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Journal of the New York Entomological Society

VOLUME LXXXIV MARCH 1976 No. 1

CONTENTS

An Evaluation of the Generic Assignment of Some American Pentatomini (Hemiptera:Pentatomidae)

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Received for Publication November 14, 1974

Abstract: Type specimens representing some of the binomina proposed by Dallas, Distant, Walker and Westwood for Pentatomini from the Americas were examined for generic placement. These names are listed and synonymy or generic misplacement noted where recognized. The following new combinations are proposed: *Acrosternum grave* (Walker) from *Nezara*; *Acrosternum montivagum* (Distant) from *Chlorochroa*; *Acrosternum scutellatum* (Distant) from *Nezara*; *Acrosternum sparnium* (Dallas) from *Nezara*; *Banasa parvula* (Dallas) from *Thyanta*; *Chloropepla luteipennis* (Westwood) from *Loxa*; *Rio politulus* (Distant) from *Holcostethus*; *Tibilis fulvicornis* (Walker) from *Brachystethus*; and *Tibilis piceola* (Walker) from *Brachystethus*.

The following new synonymy was recognized: *Acrosternum montivagum* (Distant) = *Nezara majuscula* Distant; *Chloropepla vigens* (Stål) = *Dichelops pulchricornis* (Walker); *Euschistus integer* Stål = *Trichopepla dubia* Distant; *Mayrinia curvidens* (Mayr) = *Dichelops mutabilis* (Walker); *Mormidea cubrosa* (Dallas) = *Mormidea punctifer* (Walker); *Oebalus poecilus* (Dallas) = *Mormidea prominula* Dallas; *Pharypia generosa* Stål = *Arocera nigropicta* (Walker); *Placocoris viridus* Mayr = *Mentisa smaragdina* Walker; *Thyanta antiguensis* (Westwood) = *Crato urbicus* Distant; *Thyanta* Stål = *Crato* Distant.

The generic placement of *Padeaus bovillus* Distant is incorrect and that of *Pellaea panamensis* (Distant) is suspect, but new combinations are not proposed for these species.

A lectotype and paralectotype(s) are designated where synonymy involves syntypes.

The types of most species described by Westwood, Dallas, Walker and Distant have been reexamined previously and the generic placement of the species has been changed as necessary to correct errors in assignment or to reflect refinement in classification. This has not been done recently, or at least the results have not been published, for many pentatomids from the Americas and consequently some applicable material has been missed in generic revisions.

There follows a list of some of the names proposed by the above authors

Acknowledgments: I am indebted beyond repayment to Dr. W. R. Dolling for his assistance while I worked in the British Museum (Natural History) collection, for subsequent loans of type material requiring further study and for furnishing label data that I neglected to note. Dr. I. Lansbury, at the University Museum, Oxford, Dr. P. van Doesburg, at the Rijksmuseum van Natuurlijke Historie and Dr. Per Inge Perrson of the Naturhistoriska Riksmuseum, Stockholm, loaned types pertinent to this work. To them I am grateful.

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for American species of Pentatomini. Each of these species seems to have been placed, either originally or subsequently, in the correct genus, as the genus is now understood. Many of the species belong in genera which need revision, and some of the names may not be valid. Subsequent to this list, new combinations and new synonymy are proposed and cases of doubtful generic placement are discussed. Lectotypes and paralectotypes are designated when new synonymy involves syntypes. One of these usually bears a "type" label even though the author did not designate a holotype and no lectotype has been designated previously.

I have examined all of the extant type material known upon which the names listed or discussed here are based. That of Westwood is in the University Museum, Oxford, and that of Dallas, Walker and Distant is in the British Museum (Natural History), London.

Correctly Placed Species

Aelia americana Dallas
Acrosternum dallasi (Distant)[1]
Acrosternum geniculatum (Dallas)[2]
Acrosternum nitidum (Westwood)[2]
Arocera affinis Distant
Arocera altivolta Distant
Arocera apta (Walker)
Arocera chiriquensis Distant
Arocera jalapensis Distant
Arocera nigrorubra (Dallas)
Arocera patibulata Distant
Arocera placens (Walker)
Arocera protea Distant
Arocera rufifrons (Dallas)
Arocera schumanni Distant
Banasa antica (Dallas)
Banasa discolor (Dallas)
Banasa inopinata (Walker)
Banasa salvini Distant
Banasa stalii Distant
Banasa stigmosa Distant
Boea auriflua Walker
Boea costaricensis Distant
Boea postica Walker
Boea purpurascens Walker
Brachystethus discolor (Walker)
Brachystethus rubromaculatus Dallas
Capivaccius bufo Distant
Chlorocoris aberrans Distant
Chlorocoris championi Distant
Chlorocoris hebetatus Distant
Chlorocoris irroratus Distant
Chlorocoris rubescens Walker
Chlorocoris rufispinus Dallas
Chlorocoris rufopictus Walker
Chlorocoris usitatus Distant
Cosmopepla binotata Distant
Cosmopepla conspicillaris (Dallas)
Dichelops bicolor Distant
Dichelops divisus (Walker)
Dichelops leucostigmus (Dallas)
Dichelops melacanthus (Dallas)
Disderia decorata (Distant)
Euschistus acuminatus Walker
Euschistus cornutus Dallas
Euschistus latus (Dallas)
Euschistus thoracicus Dallas
Evoplitus humeralis (Westwood)
Fecelia nigridens (Walker)
Loxa affinis Dallas

[1] Catalogued by Kirkaldy (1909) under *Nezara* subgenus *Acrosternum*, this combination is implicit in the acceptance of *Acrosternum* as a genus by Bergroth (1914) and subsequent revisors of *Nezara* and related genera.

[2] Bergroth (1914) implicitly provided new binomina for those American species catalogued by Kirkaldy (1909) under the nominate subgenus of *Nezara* when he wrote: "To *Acrosternum* belong . . . all American species wrongly placed by Kirkaldy (Cat. p. 117–118) in the 'typical subgenus' of *Nezara* (except *viridula*)."

Loxa deducta Walker
Mecocephala acuminata Dallas
Mormidea collaris Dallas
Mormidea cubrosa (Dallas)
Mormidea maculata Dallas
Mormidea pulchella Walker
Mormidea scutellata (Westwood)
Mormidea tetra Walker
Murgantia simulans Distant
Murgantia varicolor (Westwood)
Murgantia violascens (Westwood)
Pallantia macula (Dallas)
Pellaea canadens (Distant)
Pellaea sticta (Dallas)
Piezodorus guildinii (Westwood)
Runibia decorata (Dallas)
Runibia euopta (Walker)
Runibia proxima (Dallas)
Sibaria armata (Dallas)
Taurocera abruptus (Walker)
Thyanta antiguensis (Westwood)
Thyanta obsoleta (Dallas)
Thyanta testacea (Dallas)

New Combinations and New Synonymy

Acrosternum grave (Walker) NEW COMBINATION.

Strachia gravis Walker, 1867, Cat. Het. 2:322.
Nezara gravis; Kirkaldy, 1909, Cat. Hem. 1:121.

Acrosternum montivagum (Distant). NEW COMBINATION.

Chlorochroa montivaga Distant, 1890, Biol. Cent. Am., Rh. 1:333, Pl. 31, fig. 13.
Nezara majuscula Distant, 1890, Biol. Cent. Am., Rh. 1:339, Pl. 31, fig. 20. NEW SYNONYMY.

The following specimen of *Nezara majuscula* is designated LECTOTYPE: ♀, labeled (a) Type. (b) Xautipa, Guerrero, H. H. Smith. (c) Distant Coll. 1911–383. PARALECTOTYPE: ♀, labeled (a) *majuscula* Dist. (b) Panama, Boucard. (c) Distant Coll. 1911–383.

The type specimens were compared. Aside from sexual differences the type of *C. montivaga*, a male, differs from the types of *N. majuscula* in being somewhat darker due apparently to an exudation of fat, in the obscurity of the dot in each basal angle of the scutellum, and in having the juga just contiguous at the apex of the head. The black scutellar dots usually present in this species are obscure or absent in some specimens, and the degree to which the juga converge also varies, rarely becoming contiguous or nearly so. The ostiolar ruga is unusually short for the genus, extending only about halfway from the inner boundary of the ostiole to the lateral margin of the metapleuron, and in this and other critical characters the three specimens agree.

Acrosternum scutellatum (Distant). NEW COMBINATION.

Nezara scutellata Distant, 1890, Biol. Cent. Am., Rh. 1:339, Pl. 31, fig. 21; Kirkaldy, 1909, Cat. Hem. 1:121.

Acrosternum sparnium (Dallas). NEW COMBINATION.

Rhaphigaster sparnius Dallas, 1851, List. Hem. 1:280.
Nezara sparnius; Kirkaldy, 1909, Cat. Hem. 1:121.

Banasa parvula (Dallas). NEW COMBINATION.

Rhaphigaster parvulus Dallas, 1851, List. Hem. 1:279.
Thyanta parvula; Distant, 1900, Ann. Mag. Nat. Hist. (7) 5:390.

The median tubercle at the base of the abdomen removes this species from *Thyanta*. The metasternum was destroyed in pinning, but other characters are those of *Banasa*.

Chloropepla luteipennis (Westwood). NEW COMBINATION.

Pentatoma luteipennis Westwood, 1837, Cat. Hope 1:40.
Loxa luteipennis; Distant, 1900, Proc. Zool. Soc. London:821.

The long tapering ostiolar rugae place this species in *Chloropepla* rather than *Loxa*. From *C. vigens* it seems to differ in its larger size, less convex posterior sternites and more rounded posteromesial angles of the basal plates.

Chloropepla vigens (Stål, 1860).

Diceraeus pulchricornis Walker, 1867, Cat. Het. 2:250. NEW SYNONYMY.
Dichelops pulchricornis; Distant, 1900, Ann. Mag. Nat. Hist. (7) 5:431.

Walker's type agrees with the verbal description of *C. vigens* given by Grazia (1968).

Euschistus integer Stål, 1872

Trichopepla dubia Distant, 1890, Biol. Cent. Am., Rh. 1:333, Pl. 31, fig. 14. NEW SYNONYMY.

The following specimen of *Trichopepla dubia* is designated LECTOTYPE: ♂, labeled (a) Type. (b) Tepetlapa, Guerrero, 3000 ft., Oct., H. H. Smith. (c) B. C. A. Hem. I, *Trichopepla dubia*. (d) Brit. Mus. Type No. Hem. 977. PARALECTOTYPES: ♀, labeled (a) Ventanas, Mex., 2000 ft., Forrer. (b) B. C. A. Hem. I, *Trichopepla dubia*; ♂, labeled (a) as above (b) Distant Coll. 1911–383; ♂, labeled (a) *dubia* Dist. (b) Cuernavaca, Morelos, June, H. H. S.; ♀, same data.

Distant's specimens are ordinary examples of this species except that the one paralectotype whose pygophore was dissected is aberrant in lacking median penal lobes. The other male that was dissected proved normal in this respect. The latter specimen, labeled (a) B. C. A. Hem. I, Chilpancingo, Guerrero, 4600 ft., June, H. H. Smith. (b) B. C. A. Hem. I, *Trichopepla dubia* (the name in Distant's handwriting), was probably among those specimens upon which Distant based his description, but it is excluded from the paralectotypes because this locality was not mentioned in conjunction with the description.

Mayrinia curvidens (Mayr, 1864)

Diceraeus mutabilis Walker, 1867, Cat. Het. 2:250. NEW SYNONYMY.
Dichelops mutabilis; Distant, 1900, Ann. Mag. Nat. Hist. (7) 5:431.

The following specimen of *Diceraeus mutabilis* is designated LECTOTYPE: ♂, labeled (a) Type. (b) Tejuca, Jan^{y} 1857, H. Clark. (c) *Diceraeus mutabilis* (d) Brit. Mus. Type No. Hem. 1054. PARALECTOTYPES: ♂, 3 ♀♀ all labeled (a) Constancia, Jan^{y} 1857, H. Clark. (b) *Diceraeus mutabilis*, Walker's catal.; ♀, labeled (a) Petropolis Feb^{y} 1857, J. Gray. (b) *Diceraeus mutabilis*, Walker's catal.

Walker's types were compared to the holotype of *Loxa fryi* Distant, which Horvath (1925) placed in the synonymy of *Mayrinia curvidens*. They agree with the description of *M. curvidens* given by Grazia-Vieira (1972) in her revision of *Mayrinia*.

Mormidea cubrosa (Dallas)

Pentatoma cubrosa (Dallas), 1851, List. Hem. 1:247.
Eysarcoris punctifer Walker, 1867, Cat. Het. 2:274. NEW SYNONYMY.
Mormidea punctifer; Distant, 1899, Ann. Mag. Nat. Hist. (7) 4:437.

The holotypes of these species, both females, were compared and are essentially identical.

Oebalus poecilus (Dallas)

Mormidea poecila Dallas, 1851, List. Hem. 1:213 (type apparently lost).
Mormidea prominula Dallas, 1851, List. Hem. 1:213. NEW SYNONYMY.

This species is removed from *Mormidea* by the relative length of the first rostral segment and bucculae, these terminating together at the base of the head. The type of *M. prominula*, a female, has immaculate posterior femora and in this respect agrees with *Oebalus ornatus*. Most but not all specimens of *O. poecilus* have a conspicuous dark dot at the base of many femoral setae, an observation used by Sailer (1949) to distinguish females of this species from those of *O. ornatus*. The convexity of the basal plates (first gonocoxae) usually differ subtly in *O. ornatus* and *O. poecilus*, those of the latter species being slightly impressed near the lateral angle. On this basis *M. prominula* is placed in the synonymy of *O. poecilus*.

Pharypia generosa Stål, 1864

Strachia nigropicta Walker, 1867, Cat. Het. 2:318. NEW SYNONYMY.
Arocera nigropicta; Distant, 1900, Ann. Mag. Nat. Hist. (7) 5:431.

The median tubercle at the base of the abdomen and the form of the metasternum are contrary to the generic characters of *Arocera*. Stål's type was compared to a syntype of Walker's species and the two seem conspecific.

The following specimen of *Strachia nigropicta* is designated LECTOTYPE: ♂, labeled (a) Type. (b) Bras. Tapayos (upper surface) 53, 27 (lower surface). (c) *Strachia nigropicta*. PARALECTOTYPE: ♂, labeled (a) Santarem (b) *nigropicta* Stål (c) *Strachia nigropicta*, Walker's catal.

Placocoris viridus Mayr, 1864

Mentisa smaragdina Walker, 1868, Cat. Het. 3:537. NEW SYNONYMY.

China (1960) noted that Walker's specimen is a pentatomid, not a cydnid as Walker thought. The carded type agrees with the description given by Kormilev (1949) of Mayr's species.

Rio politulus (Distant). NEW COMBINATION.

Peribalus politulus Distant, 1893, Biol. Cent. Am., Rh. 1:457.
Holcostethus politulus; Kirkaldy, 1909, Cat. Hem. 1:48.

This species agrees in all respects with the generic definition set forth by Ruckes (1960) in establishing the genus *Rio*.

Thyanta antiguensis (Westwood)

Pentatoma antiguensis Westwood, 1837, Cat. Hope 1:36.
Crato urbicus Distant, 1893, Biol. Cent. Am., Rh. 1:457, Pl. 39, fig. 22. NEW SYNONYMY.
Thyanta antiguensis; Distant, 1900, Proc. Zool. Soc. London:812.

Distant's type is carded, but the genitalia of the male holotype are clearly presented and leave no doubt as to the identity of the specimen. The monotypic genus *Crato* Distant, 1893, becomes a synonym of *Thyanta* Stål, 1862.

Tibilis fulvicornis (Walker). NEW COMBINATION.

Rhaphigaster fulvicornis Walker, 1867, Cat. Het. 2:361.
Brachystethus fulvicornis; Distant, 1900, Ann. Mag. Nat. Hist. (7) 5:428.

The flat pentagonal metasternum, produced to form a nearly continuous profile with the abdominal spine and mesosternal carina, together with the rostral characters place this and the following species in *Tibilis*.

Tibilis piceola (Walker). NEW COMBINATION.

Brachystethus piceolus Walker, 1868, Cat. Het. 3:456.

Species Incorrectly or Questionably Placed, Not Reassigned

Padaeus bovillus Distant

Padaeus bovillus Distant, 1900, Trans. Entomol. Soc. London:689.

The arcuately truncate termination of the bucculae well before the distal end of the first rostral segment removes this species from *Padaeus*. It is probably near *Mormidea*, but reclassification would be venturesome until more is known of the species, of which the male is unknown.

Pellaea panamensis (Distant)

Nezara panamensis Distant, 1890, Biol. Cent. Am., Rh. 1:339. Pl. 32, fig. 1.

The type lacks the calloused rugosities on the dorsum that are characteristic of *Pellaea*. No other specimen of this form is known and it is possible that the female type represents an aberrant example of an *Acrosternum*.

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Revision of the Genus *Trichopepla* (Hemiptera:Pentatomidae) in N. America

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Abstract: A diagnosis is given for the genus *Trichopepla*; an identification key and descriptions are provided for seven species.

Trichopepla is closely related to the genus *Holcostethus*. In both genera pseudoclaspers are found within the genital cup of the male. They are smaller in *Trichopepla* and generally hidden at the base of the claspers. The spermatheca, however, is very aberrant in this genus (McDonald, 1966). All species have a very simple sac-like spermatheca, which in some species possesses a terminal appendix. This is one of the simplest type of pentatomoid spermatheca. While *Holcostethus* and *Trichopepla* have pseudoclaspers, the spermatheca of all species of *Holcostethus* unlike *Trichopepla* is typically pentatomoidean. Pseudoclaspers and normal pentatomoid spermathecae also characterize the genus *Carpocoris* (Tamanini, 1958).

It is probable that *Trichopepla* is a fairly ancient genus in which the spermathecal pump has not yet developed or is represented by the terminal appendix found in some species. It will be interesting to note if other pentatomoid genera possess either a simple spermatheca or an intermediate form between the simple type and the more complex pump found in most pentatomoids.

Key to the species of *Trichopepla* in N. America

1. Head distinctly elongate, tapering apically, ratio of width between eyes to length (apex to line across base of eyes) 1:1.3, dorsal surface often densely pilose; pseudoclaspers with numerous stout spines on surface (Fig. 4) ..... *semivittata* (Say)
   Head broadly rounded or truncate apically, ratio of width to length 1:1 or less, dorsal surface with a few hairs; pseudoclaspers with a few lateral spines at most 2
2. Pronotum distinctly impressed behind anterolateral margins; small species generally

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less than 4 mm wide (across lateral angles of pronotum) and 8 mm long (apex of head to apex of wing membrane) 4

Pronotum not impressed behind anterolateral margins, prothorax smoothly rounded to margins; larger species over 4 mm wide and 8 mm long 3

3. Connexiva with a continuous light brown or yellow margin; tip of scutellum generally pale yellow; base of pronotum and coria concolorous with dorsal surface ..... *grossa* Van Duzee

Abdominal connexiva with alternating pattern of black and light brown, sometimes faint, in which case the connexiva are uniformly amber; tip of scutellum concolorous; base of pronotum and coria often roseus ..... *aurora* Van Duzee

4. Buff or brown species with 3 distinct broad longitudinal yellow stripes alternating with black on basal half of scutellum ..... *vandykei* Van Duzee

Scutellum concolorous or at most with a thin median yellow stripe and yellow spots in anterolateral corners 5

5. Abdominal spiracles distinctly margined with dark brown or sternites uniformly fuscous around spiracles; females over 4 mm wide and 8 mm long; males with small pentagonal pseudoclaspers (Fig. 13) ..... *atricornis* Stål

Abdominal spiracles same color as sterna or at most with a very narrow pale brown ring around the spiracular rim; females smaller than above; males with more elongate leaf-like pseudoclaspers (Figs. 28, 43) 6

6. Lateral angles of pronotum broadly rounded (Fig. 39); head apex bluntly rounded; dorsal margin of pygophore with a deep median U-shaped emargination flanked by protuberances on each side (Fig. 41) ..... *pleyto* Van Duzee

Lateral angles of pronotum more angulate (Fig. 23); head truncate apically; dorsal margin of pygophore with a very shallow U-shaped emargination (Fig. 25) ..... *dubia* (Dallas)

Trichopepla Stål

Trichopepla Stål, 1867, p. 528; Van Duzee, 1904, p. 34; Kirkaldy, 1909, p. 49; Zimmer, 1912, p. 221; Van Duzee, 1917, p. 33; Blatchley, 1926, p. 107; Froeschner, 1941, p. 127.

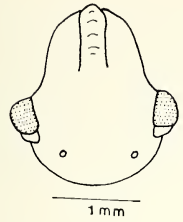
Type species. Pentatoma pilipes Dallas, 1851 (= *semivittata*)

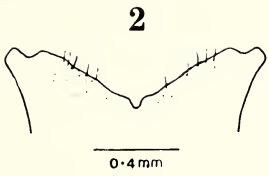
Generally small brown pilose species. 5–9 mm long (tip of head to apex of membrane) and 3–5 mm wide (across lateral angles of pronotum). Head with jugae equal to or slightly longer than tylus; apex of head truncate, bluntly rounded or distinctly tapered; bucculae elongate, narrow, extending almost the full length of head, anteriorly truncate, posteriorly bluntly rounded; apex of rostrum generally reaching hind coxae. Pronotum trapezoidal, lateral angles bluntly rounded, anterior angles acute. Pro- and mesosternum bearing a small flattened central ridge. Odoriferous gland opening with short sulcus extending ⅓ to ½ (*T. grossa* Van Duzee) distance to lateral margin, apically tapering or rounded; evaporative area narrow cephalad and caudad of sulcus on metapleuron (area somewhat larger in *T. grossa*).

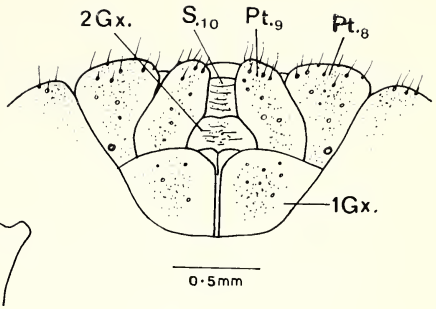
Scutellum apically narrowed and bluntly rounded abdominal sterna without spine.

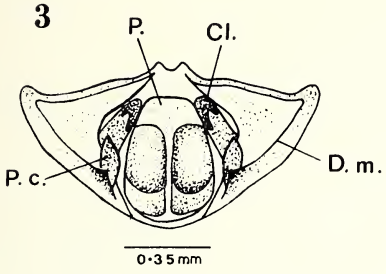
Male genitalia. Pygophore bearing small leaf-like pseudoclaspers comparable to those found in *Holcostethus* (McDonald, 1974). Claspers C-shaped, broadened and flattened apically. Aedeagus with one pair of membranous conjunctival appendages; endophallic duct long, sinuous and tapering to a fine point.

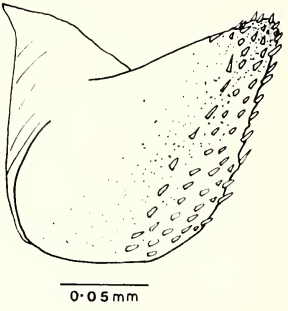
Female genitalia. External genitalia plate-like; eighth paratergites with spiracles; spermatheca a simple sac with or without a small terminal appendix; ring sclerites present on either side of spermathecal opening, latter surrounded by U-shaped sclerite.

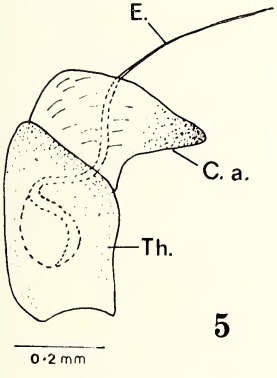


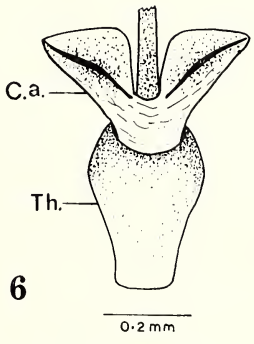


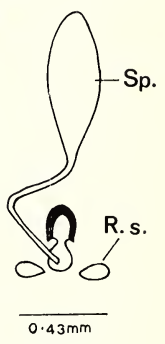




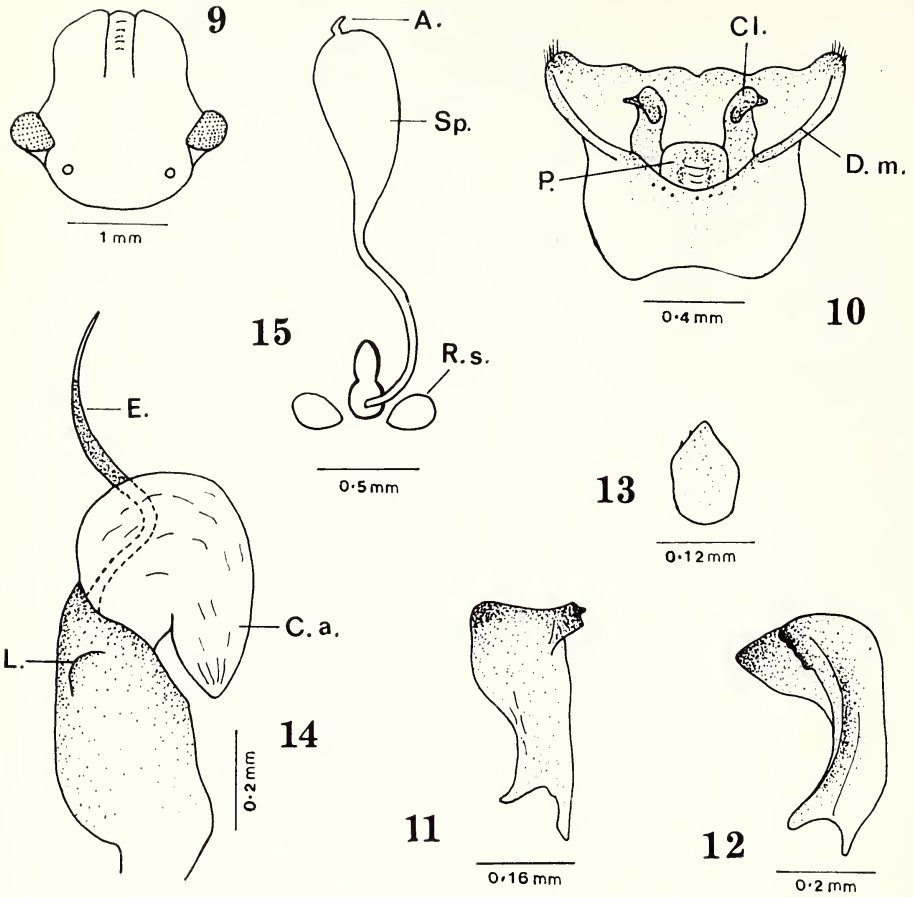








Figs. 1–8. *T. semivittata.* 1. Head, dorsal view. 2. Ventral margin of pygophore. 3. Pygophore, dorsal view. 4. Left pseudoclasper. 5. Aedeagus, lateral view. 6. Aedeagus, ventral view. 7. Female genitalia. 8. Spermatheca. Conjunctival appendage (C. a.), clasper (Cl.), dorsal margin (D. m.), endophallic duct (E.), gonocoxae 1 and 2 (1, 2 Gx.), proctiger (P.), pseudoclasper (P. c.), paratergites 8 and 9 (Pt. 8, 9), ring sclerite (R. s.), sternum 10 (S. 10), spermatheca (Sp.), Theca (Th.).



FIGS. 9–15. *T. atricornis*. 9. Head, dorsal view. 10. Pygophore, dorsal view. 11. Left clasper, outer view. 12. Left clasper, lateral view. 13. Left pseudoclasper. 14. Aedeagus, lateral view. 15. Spermatheca. Appendix (A.), endophallic duct (E.), first and second gonocoxae (1, 2 Gx.), lateral projection (L.). Other lettering as in previous diagrams.

Trichopepla semivittata (Say, 1832)

Trichopepla semivitta Stål, 1867, p. 528, Uhler, 1871, p. 96; Stål, 1872, p. 34; Uhler, 1878, p. 374; Distant, 1890, p. 64; Van Duzee, 1904, p. 34; Kirkaldy, 1909, p. 49; Zimmer, 1912, p. 224; Van Duzee, 1917, p. 33; Blatchley, 1926, p. 107; Froeschner, 1941, p. 129; McDonald, 1966, pp. 19, 52 (Genitalia).
Pentatoma semivittata Say, 1832, p. 9; Say, 1869, p. 322; Walker, 1868, Vol. 3, p. 559.
Pentatoma semivittatum Herrich-Schaeffer, 1844, Vol. 1, p. 107, fig. 766.
Pentatoma pilipes Dallas, 1851, p. 247.

Colour and colouration very variable, generally light to dark brown or rubescent with black and cream markings. Head with 3 distinct cream or light brown longitudinal stripes alternating with black or dark brown. Upper surface often densely setose, setae long.

Head distinctly tapering apically (Fig. 1), ratio of width (between eyes) to length (apex of head to line between base of eyes) 1:1.3. Antennal segments 1 and 2 pale brown, remainder may be same colour or dark brown. Anterolateral margins of pronotum slightly impressed submarginally. Connexiva generally with alternating pattern of yellow and black squares along margins, sometimes connexiva uniformly fuscous.

Male genitalia (Figs. 2–6). Described by McDonald (1966). Pseudoclaspers termed genital plates by McDonald (1966), leaf-like and covered with stout spines (Fig. 4).

Female genitalia (Figs. 7–8). Described by McDonald (1966). Ring sclerites present on either side of spermathecal opening not noted in previous description. A stout U-shaped sclerite present around spermathecal opening. Spermatheca sac-like (Fig. 8) with or without a small terminal appendix. The appendix is generally absent in this species.

Type. Not located.

Distribution. Throughout southern Canada, U.S.A. and northern Mexico.

Trichopepla atricornis Stål, 1872

Trichopepla atricornis Stål, 1872, p. 34; Uhler, 1877, p. 403; Van Duzee, 1904, p. 35; Kirkaldy, 1909, p. 49; Van Duzee, 1917, p. 34; Blatchley, 1926, p. 108.

Very similar in colouring to *T. semivittata,* usually dark brown in general appearance. Head truncate apically (Fig. 9), ratio width (between eyes) to length (apex of head to line between base of eyes) 1:1. Antennal segments all uniformly dark brown. Pronotum larger with anterolateral margins more convex than in *T. semivittata*. Connexiva generally with a continuous pale margin, sometimes uniformly dark brown.

Male genitalia (Figs. 10–14). Pygophore and claspers (Figs. 10–12) similar to *T. dubia*. Pseudoclaspers (Fig. 13) hidden below dorsal margin, small, apically tapered and with one or two minute marginal spines. Aedeagus (Fig. 14) similar to *T. dubia*.

Female genitalia. External genitalia similar to *T. semivittata*; spermatheca (Fig. 15) sac-like, generally with a small terminal appendix.

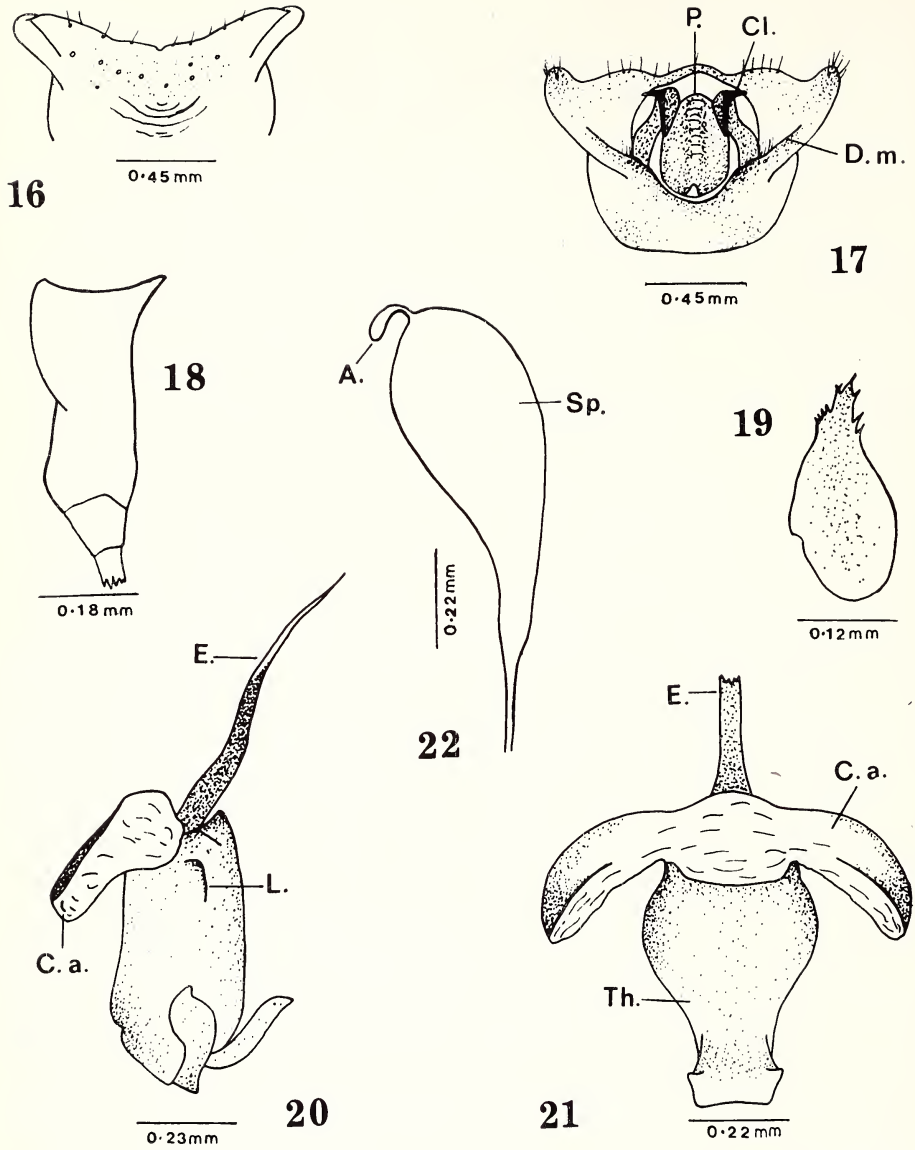
Type. From the syntype series the following specimen is designated as the lectotype: ♀ Illinois, Belfrage (labels reading Type and Paratypus attached) No 425/74, Naturhistoriska Riksmuseet, Stockholm: 4 remaining specimens are designated paralectotypes; ♀ Illinois, Belfrage (labels reading Type, *atricornis* Stål, Typus attached) No 423/74; ♀ Illinois, Belfrage (labels reading Type, Paratypus attached) No 424/74; ♀ Illinois, Belfrage, (labels reading Type, Paratypus attached) No 426/74; ♀ Wisconsin, Kumlien (labels reading Type, Paratypus attached) No 427/74.

Distribution. Illinois, Wisconsin, Colorado, Montana, California, British Columbia, Alaska, Oregon, Ohio.

Trichopepla aurora Van Duzee, 1918

Trichopepla aurora Van Duzee, 1918, p. 273.

Upper surface sparsely setose, setae short. Base of pronotum and coria often roseus. Head bluntly rounded apically, ratio of width (between eyes) to length (apex of head to line between base of eyes) 1:1. Anterolateral margins of pronotum not impressed behind. Scutellum, ratio of width (at base) to length 1:1.1. Frena well above halfway on scutellar margins.



FIGS. 16–22. *T. aurora.* 16. Ventral margin of pygophore. 17. Pygophore, dorsal view. 18. Left clasper, outer view. 19. Left pseudoclasper. 20. Aedeagus, lateral view. 21. Aedeagus, ventral view. 22. Spermatheca. Lettering as in previous diagrams.

Male genitalia (Figs. 16–21). Pygophore. Ventral margin (Fig. 16) sinuous, slightly convex; dorsal margin broadly arched (Fig. 17); proctiger oblong box-like. Claspers (Fig. 18) C-shaped, apex broadened and flattened. Pseudoclaspers (Fig. 19) elongate, flattened, with a number of marginal setae. Aedeagus similar to *T. dubia.*

Female genitalia. External genitalia similar to *T. semivittata.* Spermatheca sac-like (Fig. 22) with or without a terminal appendix.

Type. Holotype. California Academy of Sciences: ♂ Eldorado, Co. Cal. Vl. 30.13 Coll. by F. W. Nunenmacher. Paratypes: ♀ Gallatin Co. Mont. Elev. 7500 Col. E. Koch, 6/22 1900; ♂ Eldorado Co. Cal. Vl. 20.13 Coll. by F. W. Nunenmacher. Type examined.

Distribution. California, Montana, Oregon, Colorado, Washington.

Trichopepla dubia (Dallas, 1851)

Pentatoma dubia Dallas, 1851, p. 237.
Peribalus dubius Van Duzee, 1904, p. 34.
Holcostethus dubius Kirkaldy, 1909, p. 49.
Trichopepla californica Van Duzee, 1918, p. 272.
Trichopepla klotsi Ruckes, 1937, p. 2.
Trichopepla dubia NEW COMBINATION.

Note. Trichopepla dubia, Distant, 1890, Biol. Cent. Amer. Het. 1, p. 333 is a junior synonym of *Euschistus integer* Stål (L. H. Rolston, personal communication).

Small brown species often speckled with black, moderately setose on upper surface; setae long. Ratio of head width (between eyes) and length (apex of head to line between base of eyes) 1:1; head truncate or bluntly rounded apically. Anterolateral margins of pronotum distinctly impressed submarginally, lateral angles slightly acute (Fig. 23). Scutellum concolorous or at most with a fine central yellow stripe and a yellow spot in the basal angles; ratio of width (at base) to length 1:1; frenum extending almost halfway along scutellar margins. Apex of odoriferous gland sulcus rounded and raised above metasternum.

Male genitalia (Figs. 24–30). Pygophore. Ventral margin (Fig. 24) broadly emarginate with a median notch. Dorsal margin (Fig. 25) with a shallow central emargination. Claspers (Figs. 26, 27) C-shaped, flattened and broad at apex. Pseudoclaspers (Fig. 28) small, leaf-like, with one or two small spines on lateral margins. Aedeagus. Theca vasiform (Fig. 29), a lateral protuberance found on each side near margin; conjunctival appendage conical, sac-like with a ridge of sclerotization on dorsal surfaces (Fig. 30); endophallic duct elongate, sinuous.

Female genitalia. External genitalia and spermatheca similar to *T. semivittata. Type.*

Holotype. British Museum. 47–74, N. Amer.; British Museum. Type No. Hem 969. Type examined.

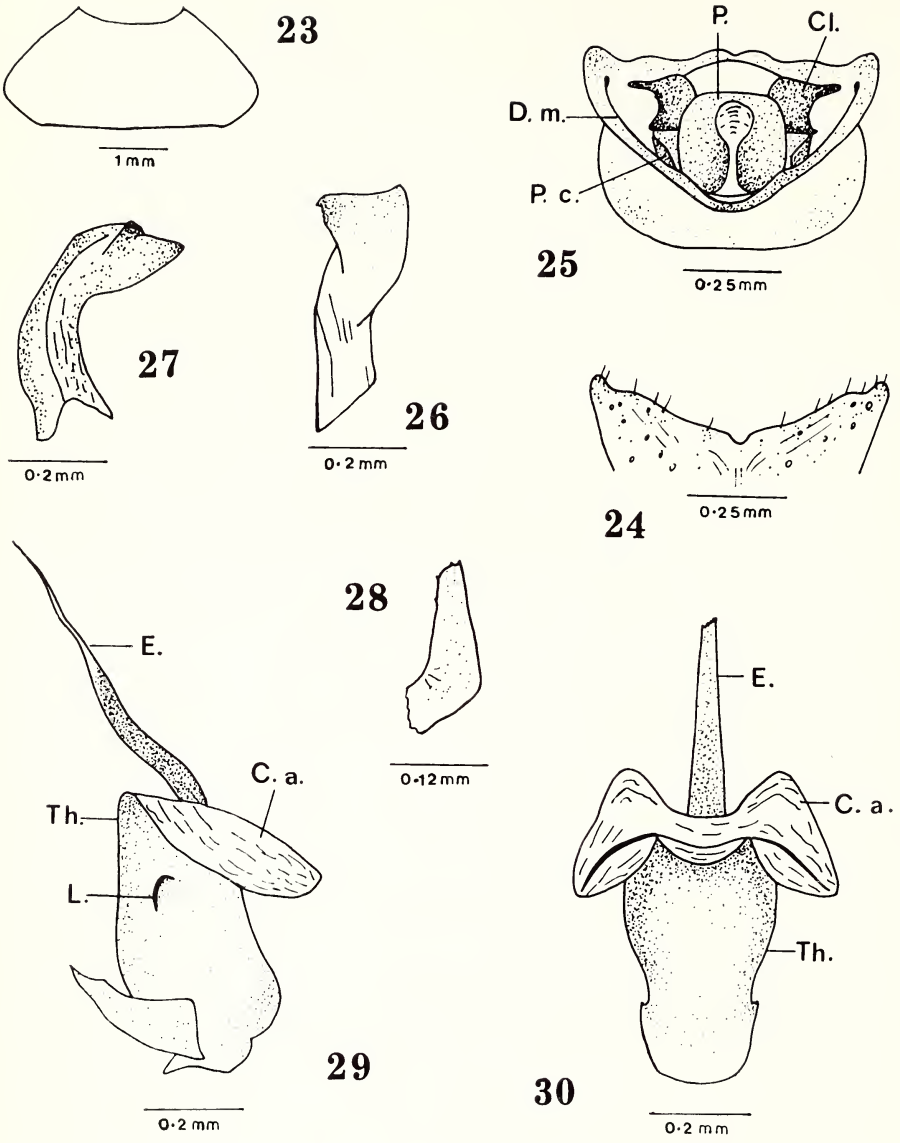
Distribution. Washington, California, Idaho, Utah, Arizona, Oregon, Colorado, Wyoming, British Columbia, Durango (Mexico).

Note. This species can be separated from *T. vandykei* by the following features. Ventral margin of pygophore with median notch (smooth in *vandykei*). Pronotum concolorous (distinctly striped yellow and black in *vandykei*).

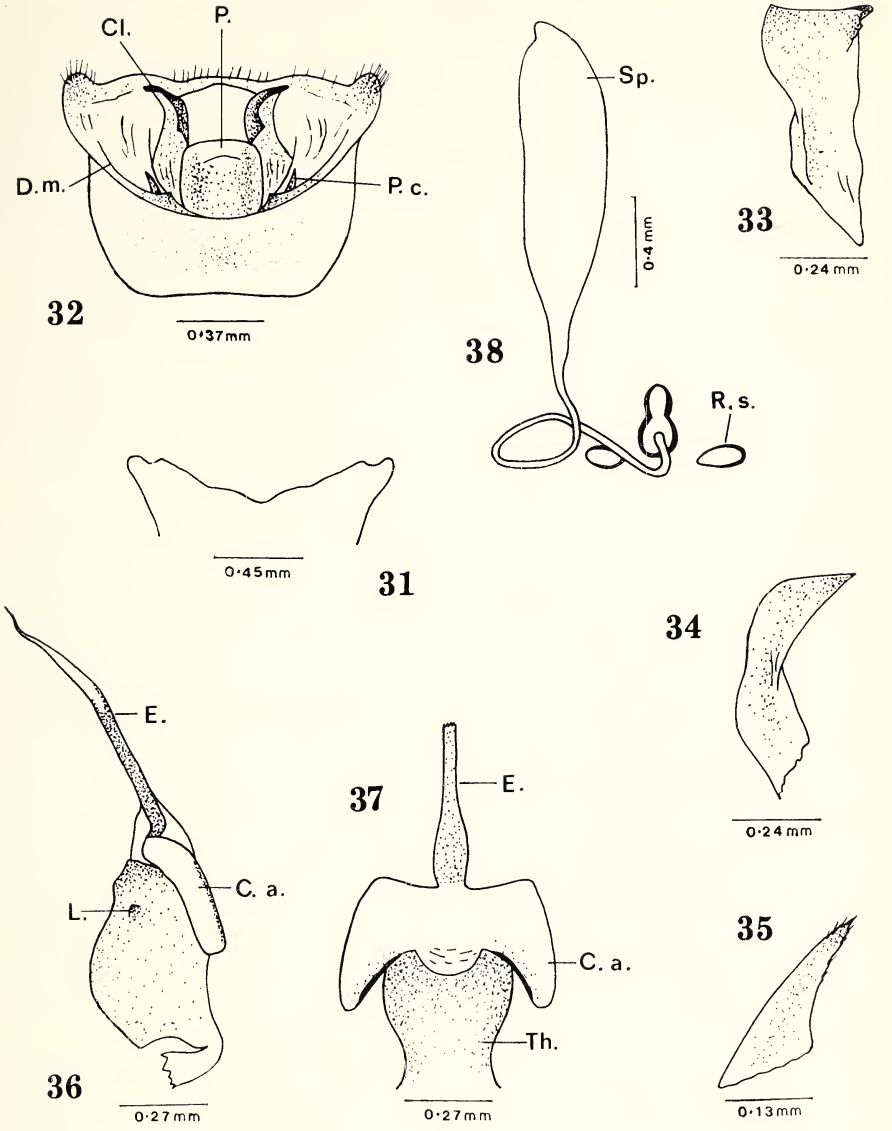
Trichopepla grossa Van Duzee, 1918, p. 274.

Trichopepla grossa Van Duzee, 1918, p. 274.

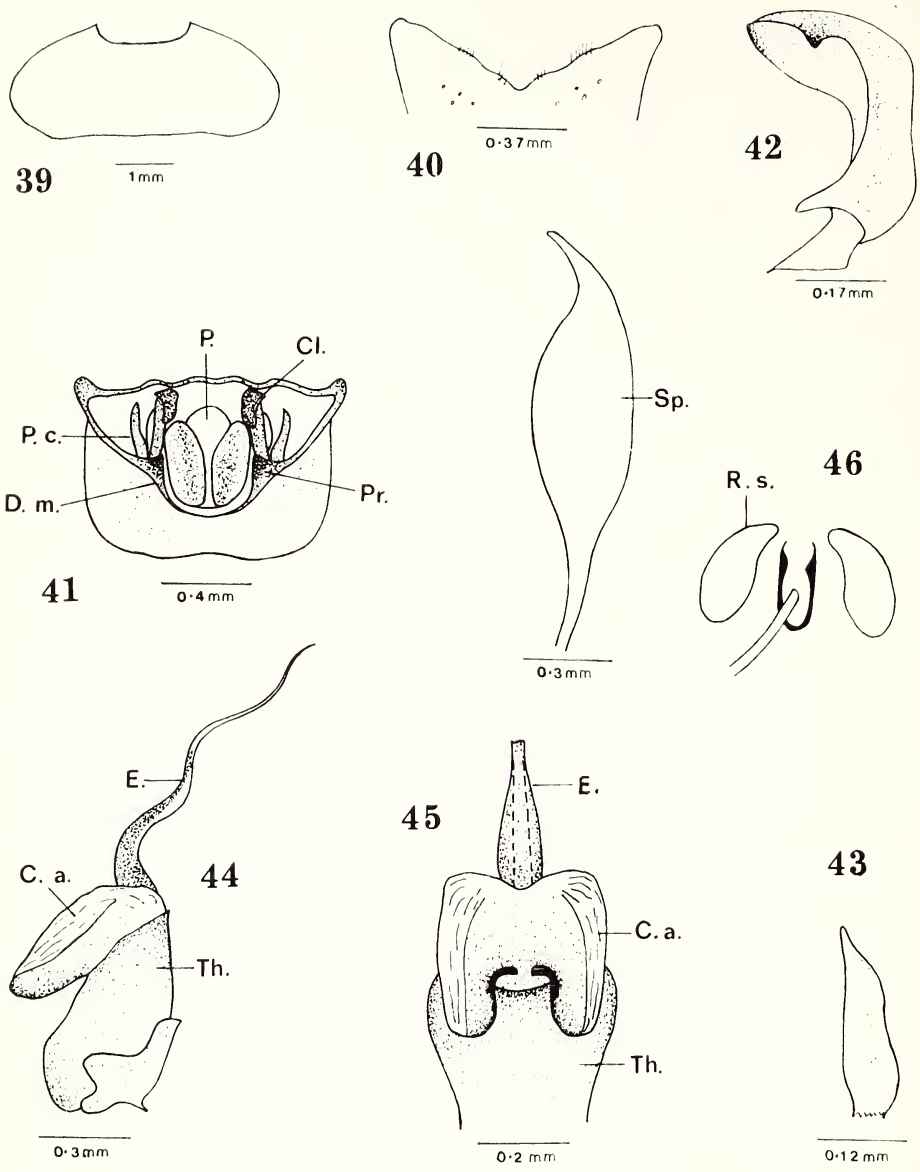
Large species, over 5 mm wide (across anterolateral angles of prothorax) and 8 mm long (tip of head to apex of membrane); dun coloured; 7 alternating broad stripes of black



FIGS. 23–30. *T. dubia*. 23. Pronotum. 24. Ventral margin of pygophore. 25. Pygophore, dorsal view. 26. Right clasper, outer view. 27. Right clasper, lateral view. 28. Left pseudoclasper. 29. Aedeagus, lateral view. 30. Aedeagus, ventral view. Lettering as in previous diagrams.



Figs. 31–38. *T. grossa*. 31. Ventral margin of pygophore. 32. Pygophore, dorsal view. 33. Left clasper, outer view. 34. Left clasper, lateral view. 35. Left pseudoclasper. 36. Aedeagus, lateral view. 37. Aedeagus, ventral view. 38. Spermatheca. Lettering as in previous diagrams.



FIGS. 39–46. *T. pleyto*. 39. Pronotum. 40. Ventral margin of pygophore. 41. Pygophore, dorsal view. 42. Left clasper, lateral view. 43. Left pseudoclasper. 44. Aedeagus, lateral view. 45. Aedeagus, ventral view. 46. Spermatheca. Protuberance (Pr.). Other lettering as in previous diagrams.

and pale brown radiating from apex of head onto anterior half of pronotum. Apex of scutellum generally with a pale yellow tip. Connexiva with a continuous pale yellow or light brown margin.

Male genitalia (Figs. 31–37). Pygophore. Ventral margin sinuous (Fig. 31). Dorsal margin with a broad central V-shaped emargination (Fig. 32). Proctiger oblong raised centrally. Claspers (Figs. 33, 34) C-shaped, apically expanded and spatulate. Pseudoclaspers (Fig. 35) triangular, a few fine setae present along margins. Aedeagus. Theca (Fig. 36) oblong with small projections one on each side near apical margins forming a shoulder; conjunctival appendages membranous, a narrow band of sclerotization on inner margins (Fig. 37). Vesica basally sclerotized, apically membranous and tapering to a fine point.

Female genitalia. External genitalia similar to *T. semivittata.* Spermatheca (Fig. 38) elongate, sac-like, with or without terminal appendix.

Type. Holotype. California Academy of Sciences, ♂ Castella, Cal. Coll. by J. A. Kusche. Paratypes, ♂ Juliaetta, Idaho; ♂ Market Lake, Idaho. Type examined.

Distribution. California, Idaho, S. Dakota, Oregon, Colorado.

Trichopepla pleyto Van Duzee, 1921

Trichopepla pleyto Van Duzee, 1921, p. 12.

Head broadly rounded, ratio of width (between eyes) to length (apex of head to line between base of eyes) 1:1. Lateral angles of pronotum broadly rounded (Fig. 39) and impressed behind anterolateral margins. Scutellum, ratio of width (at base) to length 1:1. Odoriferous gland sulcus crescent shaped, apex acute, anterior margin flush with metasternum.

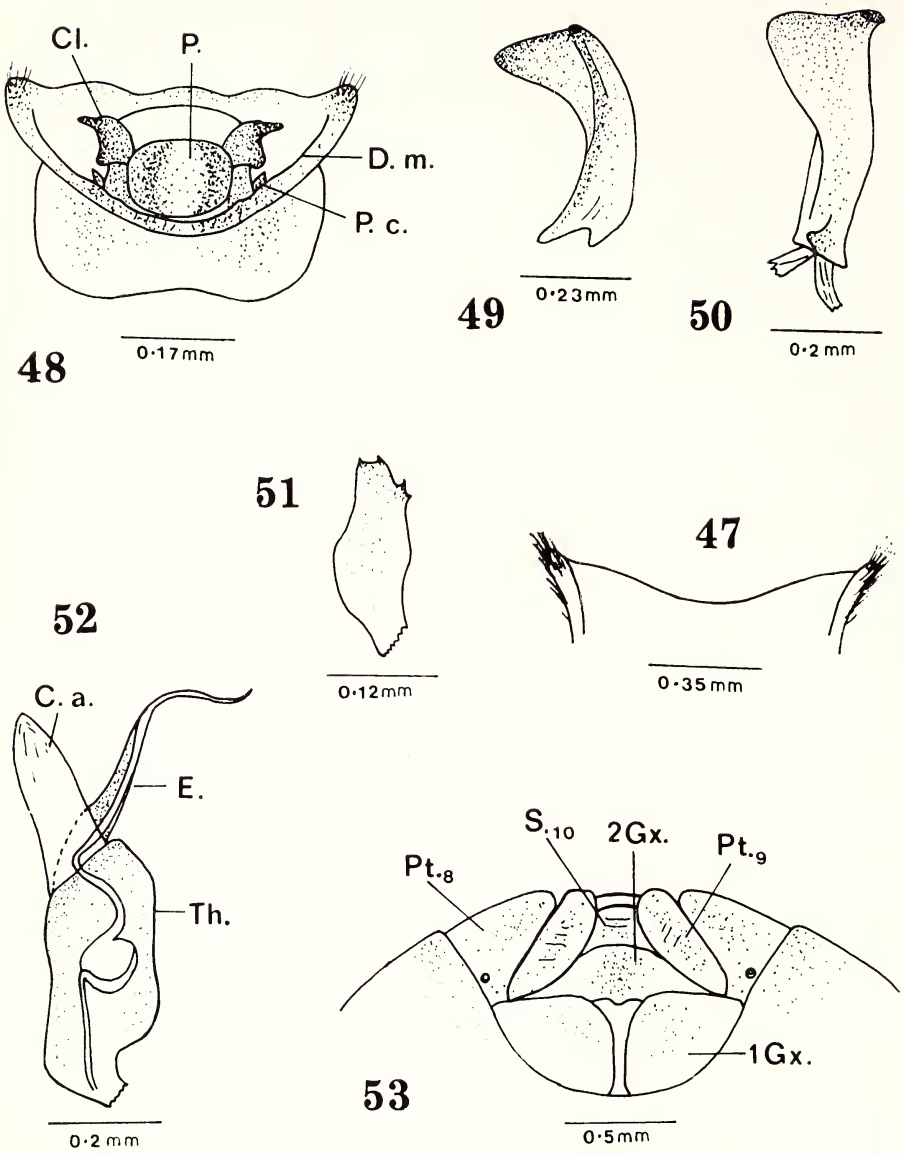
Male genitalia (Figs. 40–45). Pygophore. Ventral margin (Fig. 40) sinuous, widely V-shaped. Dorsal margin (Fig. 41) with a deep V-shaped emargination centrally and flanked by a stout protuberance one on each side; proctiger box-like. Claspers (Figs. 42, 43) broadly C-shaped, slightly expanded terminally and flattened; lower apical margin produced into a small process Aedeagus. Theca (Fig. 44) vasiform, no lateral projections. Conjunctival appendages (Fig. 45) oblong, membranous, with a band of sclerotization on inner margins; endophallic duct sinuous, elongate, tapering to a fine point apically.

Female genitalia. External genitalia similar to *T. semivittata.* Spermatheca (Fig. 46) tapering apically; spermathecal duct opening surrounded by a U-shaped sclerite; ring sclerites large.

Type. Holotype. California Academy of Sciences; ♂ Bryson Ca. Monterey Co. May 19, 1920, E. P. Van Duzee Collector; Paratypes, ♂ Pleyto Cal. Monterey Co. May 21, 1920, E. P. Van Duzee Collector; ♂ Bradley Ca. Monterey Co. May 17, 1920, E. P. Van Duzee Collector.

Distribution. California, Chihuahua (Mexico) Mexico City, Baja California (Mexico).

Note. The following features distinguish this species from *T. dubia.* Lateral angles of pronotum broadly rounded (Fig. 39), rather more angulate in *T. dubia* (Fig. 23); ventral margin of pygophore smoothly U-shaped (border with a distinct median notch in *T. dubia*; dorsal margin with 2 distinct protuberances on either side of a deep U-shaped incision (more smoothly rounded in *T. dubia*).



FIGS. 47–53. *T. vandykei*. 47. Ventral margin of pygophore. 48. Pygophore, dorsal view 49. Left clasper, lateral view. 50. Left clasper, inner view. 51. Left pseudoclasper. 52. Aedeagus, lateral view. 53. Female genitalia. Lettering as in previous diagrams.

Trichopepla vandykei Van Duzee, 1918

Trichopepla vandykei Van Duzee, 1918, p. 271.

Griscent to testaceous, broad alternating stripes of ground colour and black radiating from head to apical half of pronotum. Head broadly rounded apically. Base of scutellum

with three distinct buff stripes, one median two lateral interspersed with black or fuscous. Odoriferous gland sulcus crescent shaped, acute apically, anterior margin flush with metasternum.

Male genitalia (Figs. 47–52). Pygophore. Ventral margin smooth, gently concave (Fig. 47), a distinct tuft of setae on outer angles. Dorsal border (Fig. 48) smoothly arched. Claspers (Figs. 49, 50) C-shaped, apex flattened, spatulate and with a small finger-like projection on outer angle. Pseudoclaspers (Fig. 51) oblong, leaf-like with 3 or 4 minute marginal spines. Aedeagus. (Fig. 52). Similar to *T. pleyto*, conjunctival appendages with very little sclerotization on inner margins.

Female genitalia. Similar to *T. semivittata*, second gonocoxae slightly broader (Fig. 53). Spermatheca similar to *T. dubia.*

Type. Holotype. California Academy of Sciences, ♂ S. Francisco Co., 1X-16-06 Cal, Coll. by Van Dyke. Type examined.

Distribution. California.

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Notes on the Life Cycle and Natural History of Butterflies of El Salvador. I C.-*Colobura dirce* L. (Nymphalidae-Coloburinae)

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Abstract: All stages and instars of *Colobura dirce* L., as studied in the vicinity of San Salvador, El Salvador, Central America, are described and illustrated photographically. The larval foodplant was *Cecropia mexicana* Hmsl. Larval and adult behavior are also described. Comparisons are made of various stages of *C. dirce* and those of some more or less similar Nymphalidae, especially of the genera *Smyrna*, *Historis* and *Coea*, which belong in the Coloburinae, and not in the Limenitinae. The name "adenosma" is proposed for the ventral, eversible, odoriferous prothoracic gland present in *C. dirce* larvae, and comparable, if not homologous, to the similar structure found in many families of Lepidoptera.

This is the beginning of the fourth series of articles presenting our observations on the life cycle, larval foodplants and behavior of the early stages and adults of butterflies found in El Salvador. The present series will deal with the species of the Nymphalidae which have been grouped by different authors under the subfamily Gynaeciinae or, more rightly, Coloburinae. We think it is only fair to begin the series with the species from which that name was taken: *Colobura dirce* L.

On September 14th, 1969 we found for the first time, on a leaf of "Guarumo," a group of three larvae, velvety black, with a row of yellow spots along the spiracular area, white and yellow branched spines on the body and long horns on the black head, which pupated two days afterwards. On September 29 the adults emerged and we then realized that they were *Colobura dirce*. Since then we have reared the species a number of times starting from recently deposited eggs. The rearing has been effected in transparent plastic bags, tightly sealed with rubber bands, from which excess moisture and excreta were cleaned daily. The foodplant was replaced at the most every second day, as otherwise the larvae die when fed on even slightly decaying leaves. When pupation occurred the specimens were transferred to a wooden cage, with mosquito-net windows, where the adults emerged. Even though we are aware that under natural conditions there might be appreciable difference we kept records of the time elapsed in the different stages of the metamorphosis and

Acknowledgments: We wish to express our gratitude to Dr. A. B. Klots, who for a number of years now has been dedicating part of his valuable time to read, criticise and suggest improvements in our articles. Also to Dr. A. H. B. Rydon for providing us with reference material and a wealth of his personal experience in tropical butterflies. The authors thank also the youngest member of the team, Pierre, for his unfailing enthusiasm in field work and his tremendous capacity for observation.

of the sizes of them. Photos have been taken of the whole process and specimens preserved in alcohol, which have been sent to the American Museum of Natural History, New York. Bags and pupation box were kept indoors under ambient light and temperature conditions.

LIFE CYCLE STAGES

Egg (Fig. 1). Spherical, 1 mm diameter, dark olive-green with 11 prominent whitish-green ribs running vertically from the base, fading at the micropylar zone leaving an empty circular space where the micropyle is clearly visible. They hatch in 4 days.

First instar larva (Fig. 2). Head dark brown, slightly cordiform, with sparse thin setae. Body cylindrical, light brown when recently hatched, with sparse thin and short setae implanted on tiny conical black chalaza. Turns dark greenish-brown after feeding from the leaf and then discolored warts are clearly visible on thoracic segments 2 and 3, and abdominal segments 2, 4, 6, 8 and 9. Two mm long when hatching, about 4 mm when ready to moult in 3 days.

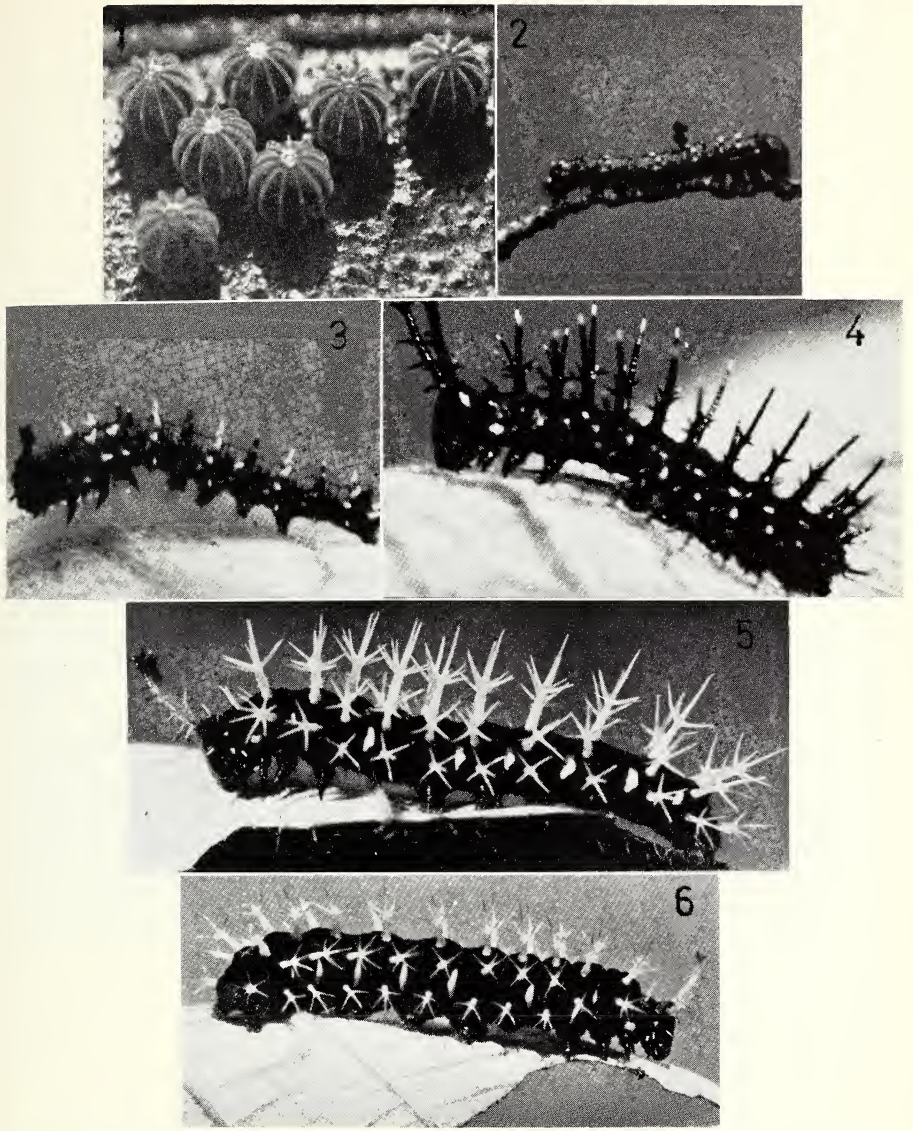
Second instar larva (Fig. 3). Head black with short, stubby horns, one on each epicranium, and armed with tiny secondary spines bearing thin setae. On the lateral borders of the head, several tiny spinulets each with a thin seta at the tip. Body cylindrical, dark brown or black, with short conical spines on all segments but 1st thoracic, which has a cervical shield with 8 spinulets. Second and third thoracic segments with subdorsal and supraspiracular, conical spines. Each abdominal segment has an additional subspiracular spine except 8th and 9th, which have the subdorsal spines only. Each of these spines bears a seta distally. The thoracic spines and the abdominals on 2nd, 4th, 6th, 8th and 9th segments are white, the rest dark brown, as are the legs and prolegs. Grows to about 7.5 mm in 3 days.

Third instar larva (Fig. 4). Head shiny black with long diverging horns (longer than head) armed with accessory spines placed in the following order: one near the base directed anterad, closely followed by three placed at the same level, two directed inwards (at an angle), one outwards; slightly higher another one parallel to the basal one, and finally a sixth directed inwards. Each horn ends distally in a knob crowned by five spinulets. Each lateral margin of the head shows two whitish small spines, fronted by a single black one. Between the horns and close to their bases, there is another small spine. The body is now shiny black also, with a row of white spots along spiracular area, starting on first thoracic segment, ending on 8th abdominal segment. On the cervical shield one of the lateral spinulets has grown about three times as big as the rest. All the spines on the rest of the body are quite long, black with light tips, and about the middle of the shaft each is armed with a rosette of secondary spines. The rosettes on the thoracic segments have 5 points, the rest have 4. Grows to 12 mm in 2 days.

Fourth instar larva (Fig. 5). Head as in third instar with longer horns, which are yellowish with black tips, and the lateral spines white. The body velvety black and spines bright yellow, the same as the spiracular row of spots. Grows to 25 mm in 6 days.

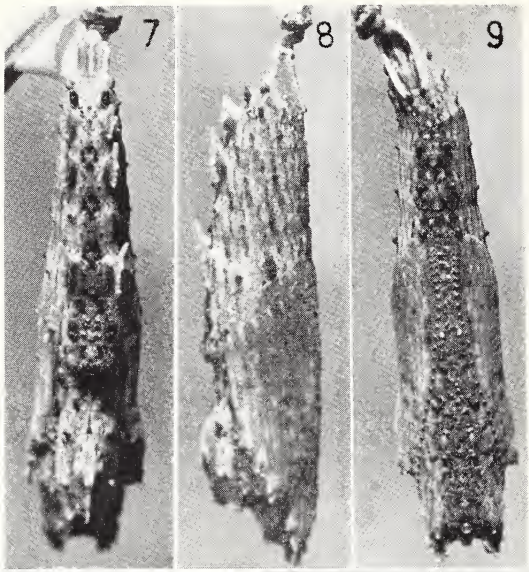
Fifth instar larva (Fig. 6). Head black with white, brown-tipped horns. Just after moulting, all spines on the velvety black body are yellow, but by the following day all thoracic spines become white, while the abdominals stay bright yellow. The spiracular row of spots also remains bright yellow. Body much thicker than head. Grows to 35–38 mm in 7–9 days.

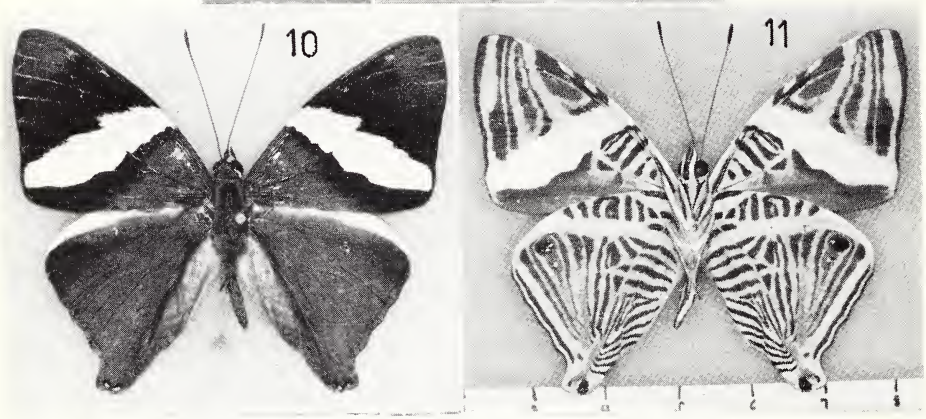
Prepupa. No color changes. Hangs with thorax incurved ventrally for 1 day.



Figs. 1 to 6. *Colobura dirce* L. 1. Eggs. Actual diameter about 1 mm. 2. First instar larva on resting perch. Notice frass pellets on the body. Actual length about 3 mm. 3. Second instar larva. Length about 7 mm. 4. Third instar larva. Length about 10 mm. 5. Fourth instar larva. Length 25 mm. 6. Fifth instar larva. Length 36 mm.

Pupa (Figs. 7–9). Cylindrical, long and thin. Light brown colored with more or less dark brown markings dorsally along meson and between wingcases. Looks in all respects like a dried piece of broken twig. On the head two ragged short prolongations following the axis of the body. Thorax slightly keeled bearing paired warts at the sides. A faint depression





FIGS. 7 to 11. *Colobura dirce* L. 7. Pupa dorsal view. 30 mm long. 8. Pupa lateral view. 30 mm long. 9. Pupa ventral view, showing movable segments. 30 mm long. 10. Adult, dorsal aspect. 11. Adult, ventral aspect. Scale in cm.

separates thorax from abdomen, which has on 4th, 6th and 7th segments short paired spines, directed posterad, mounted on winged bases. Smaller winged appendages are on 8th and 9th segments. The cremaster is very wide laterally, ending in a pointed, crochetted knob. The abdominal segments that are not provided with appendages show subdorsally small warts, same as supra- and subspiracularly, from the wing cases to 9th abdominal segment. Spiracula inconspicuous brown. Ventrally there are paired warts from 6th to 9th abdominal segments. The beaded antennae and proboscis covers form a rough-looking area from head to 6th abdominal segment, limited laterally by the smoother wingcases. Measures 28 to 30 mm long, 6 mm wide at widest points. Duration 12–14 days.

Adults (Figs. 11–12). Both males and females with same color pattern and same wing-shape. Forewing with a slightly convex costal margin to faintly pointed apex, shallowly S-shaped outer margin to rounded tornus, straight inner margin. Hindwing with convex costal margin, rounded outer angle, obliquely inwards, straight and faintly sinuose outer margin, short and thick tail-like projection at anal angle, straight inner margin with a fold. Colors dorsally: forewing dark grayish-brown basally, black apically, separated by a wide slanting light yellow band, which covers from tornus to mid-costal margin. This light yellow band turns darker as the individuals get older. Hindwing uniform dark grayish-brown with discolored narrow edge along costal margin and discolored inner fold. Two small bluish spots on tip of stubby tail. Ventrally forewing shows a discolored replica of the dorsal yellow band, surrounded by dark brown stripes, on cream ground color, some parallel to the band (basally), some almost perpendicular to it (distally). Hindwing pattern a complicated array of brown stripes on cream ground color with a thin band almost parallel to costal margin, two small eye-like spots of black, rusty red and blue close to outer angle, and two small spots on the tip of the short tail. Body, dorsally and ventrally, concolored to the respective wing surface. Eyes and proboscis brown, antennae white and brown ringed, orange tipped. Wing span about 60 mm, females being slightly larger than males.

Total developmental time under laboratory conditions, 31 to 35 days. Many individuals succumb to food poisoning, apparently, when the foodplant is slightly decaying. In the field tachinid flies are often a cause of mortality.

NATURAL HISTORY

The adults of *Colobura dirce* are very swift flyers producing a rustling noise audible from a short distance. They frequent wooded ravines, close to wooded coffee plantations, usually flying at tree-top level. They alight on tree-trunks, wings folded, head usually pointing down, and dash readily to other butterflies flying in their neighborhood, even though they are not as pugnacious as their apparently closely related species *Historis odius* and *Smyrna* spp. They even seem to get along with *Catagramma pitheas* Latreille which shares their habitat. We have observed very often, on a particular hill close to Los Chorros (about 10 km from San Salvador), that males will show up at the top of the hill from 12:30 to 13:00 hrs. and will dash from tree to tree, occasionally chasing other butterflies until about 16:30, when they move to lower areas. We have never seen adults visiting flowers. They are often seen feeding on sap oozing from tree wounds, at times on fecal matter, decaying fruits and mud puddles.

The females deposit their eggs in irregular groups, ranging from 1 to 10, on the upper or on the undersurface of "Guarumo" leaves. There seems to be no preference as to the age of the leaf, as we have found eggs on very young and on mature leaves. They do seem to prefer young trees: many times we found eggs and larvae on trees less than 1 m tall, and even on seedlings, with leaves not yet fully formed, less than 30 cm high.

The larvae upon hatching eat the upper part of the eggshell and leave the walls untouched. If they come from a group of eggs the young larvae move together to the nearest edge of the leaf. Remaining close to each other they

start feeding on it and each one constructs a resting perch with frass pellets. They maintain the perch-making habit throughout the following two instars. During 4th and 5th instars they usually stay on the underside of the leaves. While they still make the perches, they start making them at longer distances from each other as they grow but still on the same leaf. The group might dissolve altogether during the late instars. The larvae, even first instar ones, gnaw the prominent ribs at short intervals on the undersurface, apparently to control the flow of plant fluids on the tissues they are consuming, somewhat similar to what we have witnessed in *Danaus* spp. feeding on *Asclepias*, in *Lycorea ceres* when feeding on *Carica papaya*, various Heliconiidae feeding on Passifloraceae, and even some Sphingidae feeding on *Euphorbia pulcherrima* Willd. When several large larvae are congregated on the same leaf, this gnawing of the ribs might cause the collapse of the leaf lobes around their petiole, giving an aspect of a semiclosed umbrella, which has been interpreted as a protection device by some authors. In our experience the collapsing of the leaf only happens when there are several larvae together and only when they are in the 5th instar, and we consider it to be an accidental happening caused by the controlling gnawing of the ribs. The larvae, when together, do not show belligerent reactions against each other and often three to five large larvae are seen resting closely parallel to each other. The larvae of *C. dirce*, like several others belonging to other groups (among the Nymphalidae, Morphidae, Brassolidae, etc.), have a mid-ventral eversible gland placed anterad of the prothoracic legs, which is extruded when disturbed, producing a faint scent. This gland is readily noticeable during the final larval instars. Prior to pupation the larvae, if still gregarious, scatter and look for a convenient place to pupate, most of the time on the same foodplant, but also on clinging vines. At that time they stop feeding and empty their digestive tracts, ejecting a green fluid mixed with excreta.

The prepupal larvae hang from their anal prolegs, thorax incurved ventrally, for one day.

The pupae hang loosely from their pointed cremaster vertical to the ground, and swing freely at the faintest breeze or movement of the plant. This fact completes the "dry-broken-twig" effect which the shape and color of the pupae evoke, not exceeded by any other Rhopalocera. The pupae when molested react by lateral swings, always reassuming the perpendicular position. The pupae darken slightly when the adult is ready to emerge.

The adults emerge rapidly and hang from the pupa shell while expanding the wings and ejecting a rusty-brown meconium. In about 20 minutes they are ready to fly. The aggressive temperament and the striking combination of colors of this species are anything but cryptic. Larvae collected in the field while in late instars very often yield tachinid parasites.

The foodplants are Moraceae. The preferred one is a tree locally known as "Guarumo" (*Cecropia mexicana* Hmsl. and *peltata* L.), but at times another Moraceae not determined, which is shared with *Adelpha melanthe* Bates, is used. All the food-plants are rather common along ravines, road shoulders and wooded land. Both species of *Cecropia* are very similar and it would need a specialist to tell them apart. They usually have naked trunks with a few radiating branches high from the ground, each one crowned by an umbrella-like mass of long petiolated, deeply lobed (up to 13 lobes) leaves which may be over 50 cm in diameter. The trunks are hollow and often inhabited by very viciously biting ants, making an interesting case of symbiosis. According to Standley (1922) the tree is widely used in Tropical America for popular medicine due to the causticity of its fluids and its digitalis-like properties. Its sap contains also rubber but not in commercial concentration. Calderon and Standley (1941) state that the leaves of this plant mixed with salt, help deliveries of cattle. It is to be noted that the very young plants do not have peltated leaves, but entire, cordate leaves at first, which later become trilobed. When the tree has grown about 1.5 m the leaves finally grow multilobed. This fact has caused some authors to misidentify the plant, which has produced confusion about the foodplant in their reports. *Cecropia* trees are known in Brazil as "Embauba" among other vernacular names, a name that has been mentioned in several works in relation to other species of butterflies, without giving the scientific name. In El Salvador, *Cecropia* spp. are found from sea level up to about 2000 m altitude. *Colobura dirce* is also found within that range.

DISCUSSION

Colobura dirce has often been called in the literature *Gynaecia dirce* L. According to Hemming (1967) the generic name *Gynaecia* Doubleday is an objective junior synonym of *Colobura* Billberg.

Müller (1886) made a detailed description of the early stages, giving *Cecropia pachistachia* Trei as the foodplant in Brazil. According to this author, Dewitz, Stoll and Sepp had made some partial observations on the early stages also, but with many inaccuracies. The larvae and pupae are mentioned briefly by Seitz (1924) who does not however give the foodplant. Dyar (1912) also described the larva without mentioning the foodplant. All of these authors used the name *Gynaecia dirce*.

C. dirce has been classically considered to be closely related to the species of the genera *Smyrna*, *Historis* and *Coea*, as well as to others non-existent in El Salvador. *Colobura* (= *Gynaecia*) was the first one named (as *Papilio dirce* by Linnaeus, in 1758, later *C. dirce* by Billberg in 1820, and *Gynaecia dirce* by Doubleday in 1844); thence the group has been called Gynaeciidae (Seitz, 1924) or Coloburinae (Ebert, 1969). Some modern authors include some of

the species related to *Colobura* in the Subfamily Limenitinae, tribe Limenitini (Klots, 1960), or in the Subfamily Nymphalinae, tribe Limenitini (Ehrlich & Ehrlich, 1961), but they warn that the arrangement of subfamilies and tribes, as it is now, is rather a compromise, due to the incomplete knowledge about many tropical butterflies, in particular Neotropical.

We will compare the various stages of *Colobura dirce* with the equivalent stages of other Rhopalocera and specially with these of the species belonging to the alleged group of the Coloburinae.

The egg of *C. dirce*, in a very broad aspect, resembles the egg of other Nymphalidae: *Apatura* spp., *Victorina* (= *Metamorpha*) *epaphus* Latreille (Young, 1972), *V.* (= *M*) *stelenes* (Young & Muyshondt, 1973 b), and their close relatives *Anartia fatima* Fab., *A. jatrophae* Johanson, *Precis genoveva* Stoll, because they are also spherical with vertical ribs; but the eggs of these others have more ribs than those of *Colobura*: those of *Apatura* with 16 which end in a series of rounded cells around the micropyle; those of *Victorina* with 17 half of them fading before reaching the micropyle. The egg of *Historis* is spherical and has 23 ribs, which do not reach the micropylar area but form an intricate pattern of hexagons around it. The ribs of *Historis* egg in addition have a host of tiny, thin spinulets, which is an unique characteristic among the eggs of butterflies we have seen. The eggs of *Smyrna* spp. do have the same number of ribs as in *Colobura*, but the base is more flattened, which gives the eggs a different aspect. Of these species only *Colobura* deposits the eggs in clusters.

The naked, fusiform larvae of *Apatura* spp. in no way resemble the spiny, cylindrical larva of *Colobura*. The larvae of *Victorina* and related species do resemble that of *Colobura* in a superficial way, as they are cylindrical, velvety black, spiny and with long horns on the head. Under closer examination, though, we see that the horns, the shape and location of the body spines are different, and that there is an additional mesal row of spines in *Victorina*. The larvae of *Smyrna* have the head more spiny than that of *Colobura*, and are armed with short, thick horns. *S. blomfildia* also has an additional mesal row of spines (which is lacking in *S. karwinskii*). The heads of *Historis* and *Coea* resemble very much that of *Smyrna*. The body does not have the mesal row of spines, but these are shorter than in *Colobura*. The larvae of *Apatura*, *Smyrna*, *Historis* and *Coea* are solitary and have the perch-making habit. Those of *Victorina* and allies are also solitary but do not make perches. The latter feed on Acanthaceae exclusively and *Apatura* on Ulmaceae. Both *Smyrna* feed on various Urticaceae, while *Historis* and *Coea* on *Cecropia* spp.

The differences between *C. dirce* and the species mentioned are more evident in the pupae. Those of *Apatura* are green, flat and very humped dorsally. Those of *Victorina* are green, spindle-shaped with some spines protecting the

dorsal part of the abdomen. Those of *Smyrna* are brown, naked, very plump. Those of *Historis* and *Coea* (very much alike) are elongated, dorsally humped, with a row of dorsal spines along the meson, and two long head projections. As described in the life cycle, the pupa of *Colobura* is long, thin, cylindrical and light brown, in all respects like a fragment of dry twig. Among the Papilionidae we have found pupae which look also like a piece of wood, mostly in *Papilio anchisiades*, but in this case the pupa is much thicker and more or less conical and does not have appendices on the body.

The shape and coloration of the adults of the various species compared here are very different from each other, with the exception of both *Smyrna* which are much like each other in color and shape. *Historis* and *Coea* have the same coloration, but not the shape. As for behavior, the adults of *Apatura*, *Smyrna*, *Historis* and *Coea* do have many points in common with *Colobura*: fast rustling flight, tree perching, feeding habits and a pugnacious territorial defense. But it is also true that these traits are shared by many other species of genera which nobody would even think of putting together with *Colobura*, such as *Anaea* spp., *Prepona* spp., *Catonephele* spp. and many others. In this respect *Victorina* does not resemble any of the species cited at all.

A point which would seem to put *Smyrna* out of the group is its striking sexual dimorphism, not present in the rest of the species here considered. But this paradoxical difference occurs also in other well defined groups: within the Catonephelinae, we have *Catonephele numilia esite* (Muyshondt, 1973 a), *C. nyctimus* and *Epiphile adrasta adrasta* (Muyshondt, 1973 b) with strong and evident sexual dimorphism; but then we have *Temenis laothoe liberia* (Muyshondt, 1973 c), *Pseudonica flavilla canthara* (Muyshondt, 1973 d) and *Pyrrhogyra hypsenor* (Muyshondt, 1974 a) without sexual dimorphism. So the presence or absence of sexual dimorphism does not seem to be a strong criterion to determine close relationship between genera. Nor does the number of rows of spines, as otherwise two species as closely related as *S. blomfildia* and *S. karwinskii*, as evidenced in all respects except the number of rows of spines in the larval stage, would belong to different groups.

We consider it very questionable to place *Colobura*, *Smyrna*, *Historis* and *Coea* with the Limenitidi, where *Limenitis* and *Adelpha* belong without the least doubt, as they have nothing in common: shape of eggs, larvae, pupae or adults. Their behavior also show more discrepancies than resemblances. The only point in common in certain species of *Adelpha* (*melanthe* and *lerna*, in our experience), with some species of the so-called Coloburinae, is the use of Moraceae as foodplants. The rest of the *Adelpha* we have reared (*celerio*, *fessonia*, *albifilum*, *basiloides* and *iphicla*), use Rubiaceae or Melastomaceae. So this factor is not consistent either.

It is to be noted that the eversible gland located anterad of the prothoracic

legs, which is present in *Colobura dirce*, exists also in a number of other species of Rhopalocera and even in many Heterocera. In our experience we have noticed it in *Morpho peleides* and *M. polyphemus* (Young & Muyshondt, 1973 a, 1972), several species of *Anaea* (Muyshondt, 1974 b, c, 1975), *Caligo memnon*, *Opsiphanes tamarindi*, *Manataria maculata*, various species of *Taygetis* and *Chlosyne*. Müller (1886) in the chapter "Rückblick auf die Brassolinae" mentions that the larvae of Brassolinae are provided with a "Stink-wulst" (stink-pimple) which is also present in many other larvae: all Nymphalidae subfamilies, Danaidae and Hesperidae, and which apparently is lacking in Pieridae and Erycinidae. Peterson (1948) states also that such a gland is found in various larvae of Lepidoptera, and he draws several Rhopalocera larvae (*Polygonia* sp., *Euptoieta claudia* Cramer, *Nymphalis antiopa* L.) and several Heterocera larvae as well, with the gland extruded and clearly marked. According to Dr. A. B. Klots (personal communication) at least many Notodontidae larvae show that gland. We have been unable to find a name for that gland in particular, which in our observations produce a scent more or less strong, and at times very unpleasant. The dorsal V-shaped odoriferous gland of the Papilionidae larvae is called an *osmeterium*. This ventral prothoracic gland is a short, rather thick, bulbous, eversible projection of variable color, not forked. We propose the name *adenosma* for it, if it has not been previously named otherwise. (From the greek *adenos*, gland, and *osme*, smell.)

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Dermatophagoides farinae: The Supracoxal Glands[1]

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Abstract: The structure and possible function of the supracoxal glands of the house-dust mite, *Dermatophagoides farinae*, have been described. Light and electron microscopical techniques were used to study this extremely complex gland. There is one pair of supracoxal glands in the house-dust mite. Each gland is composed of eight cells that make up four two-celled functional units. Three of the two-celled units are similar to each other, whereas the fourth unit is smaller with a distinctly different morphology. The cells of the glands are characterized by several criteria, but common to all are numerous mitochondria, infolded cell membranes, microtubules, and a cuticle-lined duct. The ducts of all the functional units have a point of common attachment from which an anteriorly directed duct goes to the outside. Repugnatorial and osmoregulatory functions are discussed.

The coxal glands of several species of mites and ticks have been studied at the level of resolution of the light microscope (e.g. Grandjean, 1937a, 1937b; Lees, 1946; Moss, 1962; Prasse, 1967; Woodring, 1972). With the additional aid of scanning and transmission electron microscopy it is now possible to report on the structure of the supracoxal glands in *D. farinae* Hughes, 1961.

Previous studies on anatomical details of *D. farinae* have considered the lateral opisthosomal dermal glands (Brody and Wharton, 1970) and the digestive system (Wharton and Brody, 1972; Brody, *et al.*, 1972). The dermal glands and the digestive system are two sites of production for materials which are deposited in house-dust by *D. farinae*. The house-dust mite has been implicated as a source of allergen by a number of investigators (see van Bronswijk and Sinha, 1971, for a literature review), and secretions of the supracoxal glands may play a role in this situation.

MATERIALS AND METHODS

Mites cultured in the Acarology Laboratory were used in this study. Whole mounts were observed by phase contrast light microscopy and scanning electron microscopy, and sections were observed by bright field light microscopy and transmission electron microscopy. All specimens were prepared according to procedures described in Brody *et al.*, 1972.

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RESULTS

Dorsal to coxa I of the house-dust mite are sclerotized plates designated as supracoxal sclerites (Fig. 1). Each sclerite has a fossa (Grandjean, 1937a) which is circumscribed by a heavy cuticular ridge (Fig. 2). In the center of the fossa are three obliquely directed cuticular folds which hide the external orifice of the supracoxal gland (Fig. 3). The orifice is actually a slit-like opening which is surrounded by an internal sclerotized ring (Fig. 3). A medially directed extension of the supracoxal fossa is covered by a dorsal cuticular flap that forms the margin of the sclerite (Fig. 2). This extension of the fossa covers a narrow channel that progresses medially, ventrally, and anteriorly, over the dorsal aspect of the palpal coxa to ultimately communicate with the pre-buccal cavity (Fig. 2). Within the limits of the heavy cuticular ridge and ventral to the oblique folds is a gutter-like groove which runs ventrally and medially from the supracoxal sclerite to the region between the coxa of leg I and the gnathosoma (Figs. 2 & 4). This groove does not communicate with the pre-buccal cavity. Ventral to the groove and the oblique folds on the sclerite is the spike-like supracoxal seta of leg I. The base of the seta originates from beneath a cuticular flap and the tip points ventromedially (Fig. 4).

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Fig. 1. Scanning Electron Micrograph (SEM) of a female North American House-Dust mite *Dermatophagoides farinae*. The supracoxal sclerites (arrowheads) are situated between the coxae of leg I (C) and the gnathosoma (G). × 500.

Fig. 2. A closer view of the supracoxal sclerite by SEM demonstrates the heavy cuticular ridge (R) dorsal to the sclerite and three cuticular folds (small arrowhead) within the supracoxal fossa. An extension of the ridge (arrow) covers a channel which goes dorsally over the rim of the palpal coxa (PC). A gutter-like grove (double arrowhead) runs between the coxa of leg I (C) and the ventral gnathosoma. × 5000.

Fig. 3. Light photomicrograph of the sclerotized ring (arrowhead) which surrounds the orifice of the supracoxal gland. × 800.

Fig. 4. The SEM provides a postero-lateral view of the supracoxal fossa (F), the dorsal cuticular ridge (R), and the ventral gutter-like groove (arrowhead). The supracoxal seta (S) of leg I is directed anteromedially. × 2000.

Fig. 5. Diagrammatic representation of the dorsal functional unit of the supracoxal gland. The peripheral cytoplasm of cell type A (A) has numerous fimbria (arrow). Cell type A surrounds one end of the duct (D) and all of cell type B (B). Cell type B envelops most of the duct. Nucleus (N).

Fig. 6. A medial view of the three similar functional units. The fimbriated portions (arrow) of the ventral cell extend laterally into the coxa of leg I. The type A cells (A) surround the type B cells (B). The fimbria of the dorsal unit form the most dorsal aspect of the supracoxal gland. The medial unit is designated by arrowheads. Nuclei (N).


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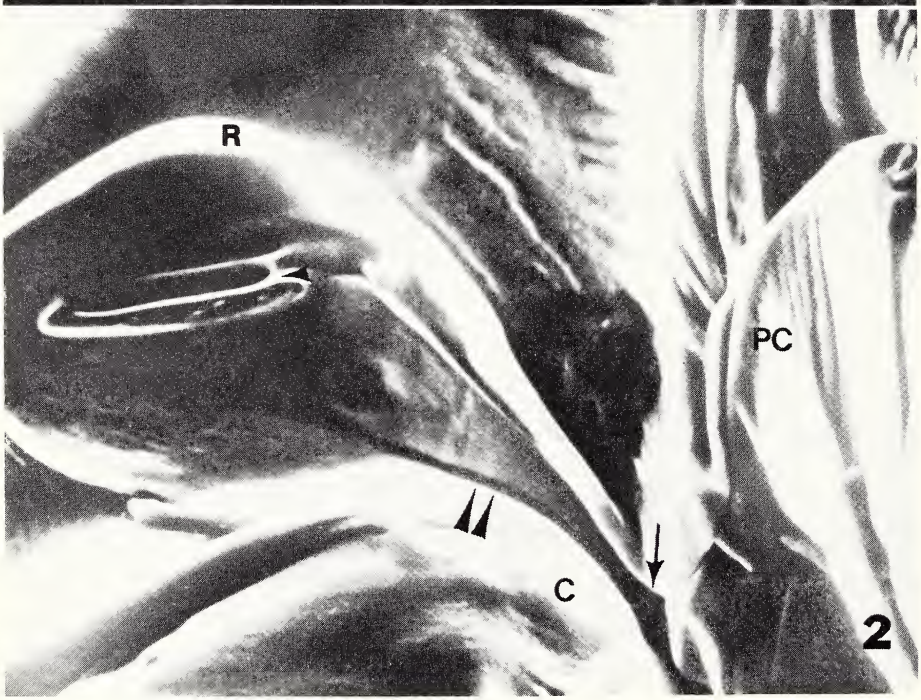
1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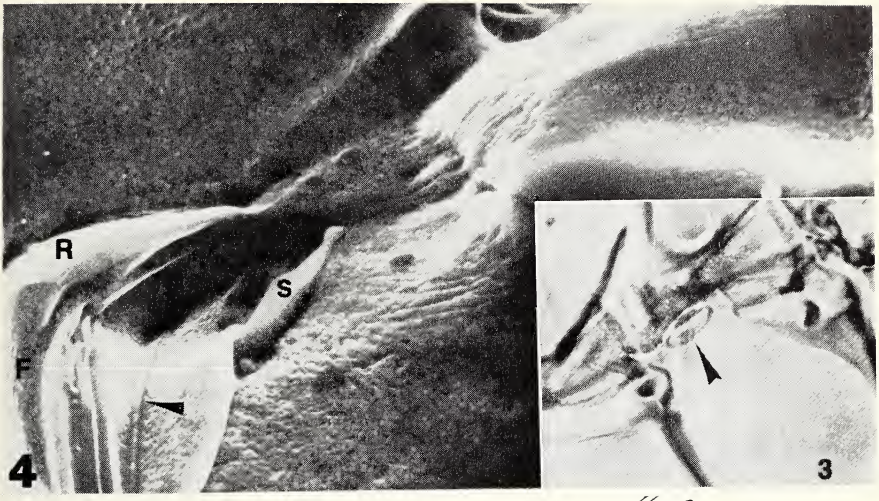
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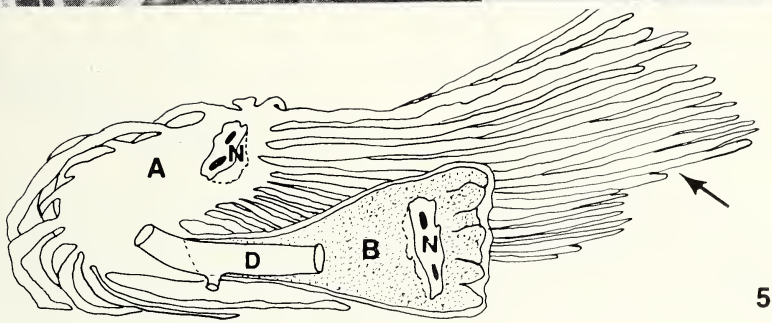
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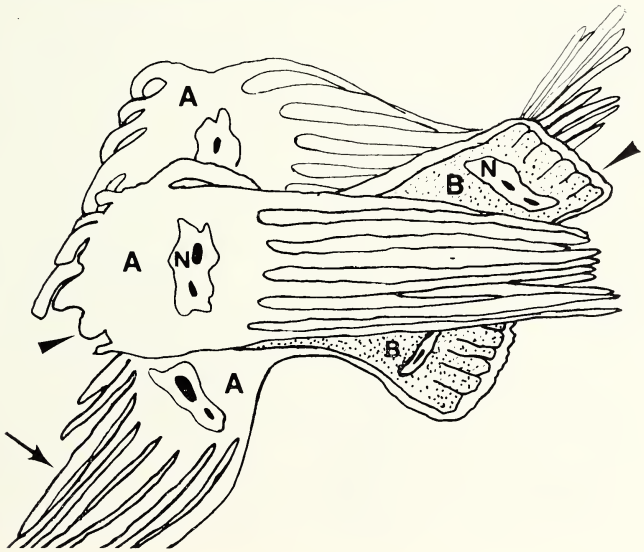
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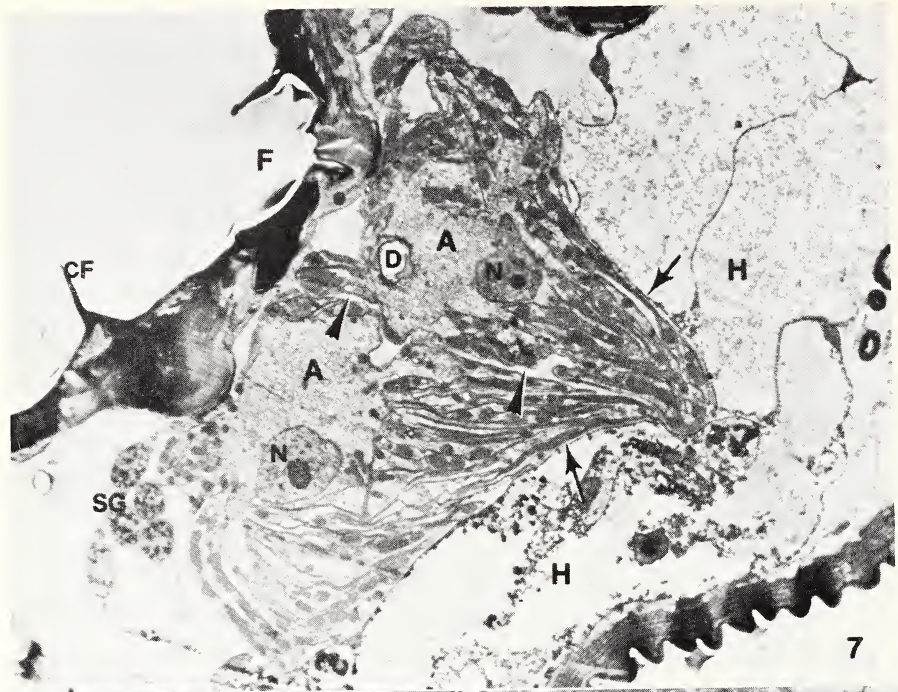
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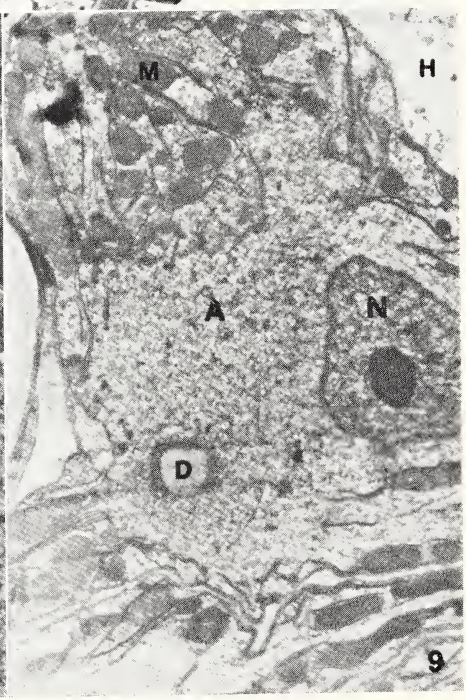
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There is one pair of supracoxal glands in the house-dust mite. Each gland has an overall dimension of about 35 microns in dorsal-ventral aspect and approximately 70 microns in anterior-posterior aspect. The glands are located posterior to the supracoxal sclerite, anteriorly and laterally within the propodosoma, and each gland has its single external orifice dorsal to the coxa of leg I (Fig. 2), within the fossa of the supracoxal sclerite.

Each gland is composed of eight cells that make up four two-celled functional units each with a cuticle-lined duct (Fig. 5). Three of the two-celled units are similar to each other (Fig. 6). The fourth unit is smaller with a distinctly different morphology (Figs. 18 & 19).

The three similar units (Fig. 6) have the largest cell of the unit named the type A cell. This type is characterized by a cell body that contains the nucleus and by great numbers of folded membranes that are thrown out into cell processes (Fig. 7). Numerous mitochondria are lined up along the membranes (Figs. 7 & 8). Thus, most of the periphery of the A cell is made up of folded membranes and adjacent mitochondria. The cytoplasm of the cell body is highly granular internal to the peripheral mitochondria (Fig. 9), and there are no recognizable organelles other than the single distinct nucleus (Figs. 7 & 9) and a few microtubules with no particular orientation (Figs. 8 & 9).

The type A cell envelops the second cell type, or type B cell, of the functional unit (Figs. 5 & 6). The type B cell (Fig. 10) is also characterized by folded membranes though they do not form the elongated processes which typify the type A cell. Numerous peripheral mitochondria are associated with the membranes of the B cell (Fig. 11). The internal cytoplasm contains a single nucleus, and is replete with microtubules which are directed along the long axis of the cell (Fig. 12). The type B cell also contains a cuticle-lined duct which is oriented in the same direction as the microtubules (Figs. 8 & 10). The mitochondria of the type B cell are similar in appearance to those of the

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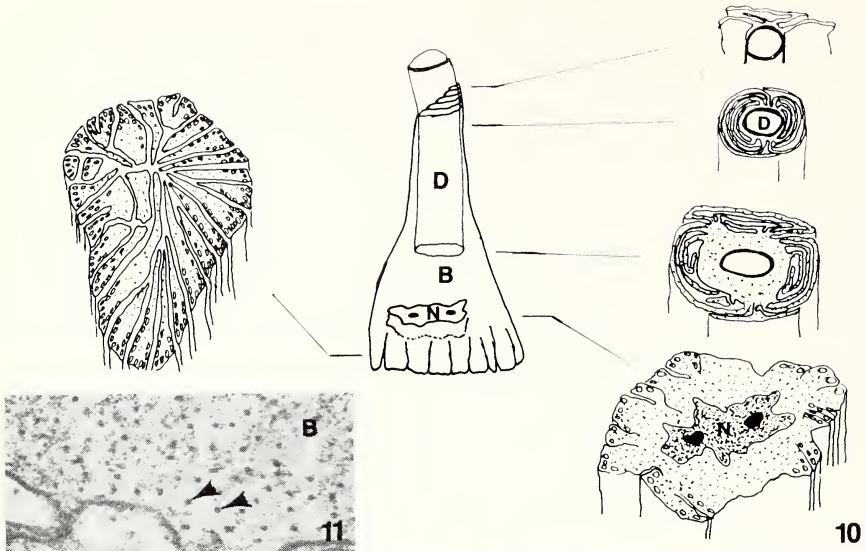
Fig. 7. Transmission electron micrograph (TEM) of a cross-section through the dorsal and medial functional units. This section has revealed a duct (D) within the cytoplasm of one type A cell (A). Fimbriated portions (arrows) of the type A cells, with numerous mitochondria, are adjacent to the haemocoel (H). Cuticular folds (CF) are within the supracoxal fossa (F) and a portion of a multinucleated salivary gland (SG) lies medial to the supracoxal gland. Nuclei (N) of the type A cells are obvious as is the intercellular space (arrowheads) of the two type A cells. × 1500.

Fig. 8. A higher magnification of the cuticle-lined duct (D) within a type A cell (A). The A cell, with its peripheral mitochondria (M), is posterior to the supracoxal sclerite (SS). × 5000.

Fig. 9. The end of the duct (D) within the type A cell (A) is capped. The nucleus (N) is obvious, and peripheral mitochondria (M) within the fimbria are seen. × 2500.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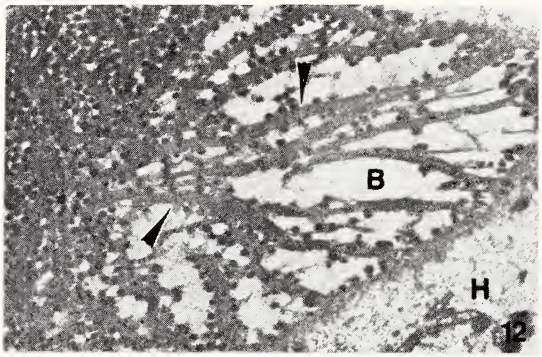
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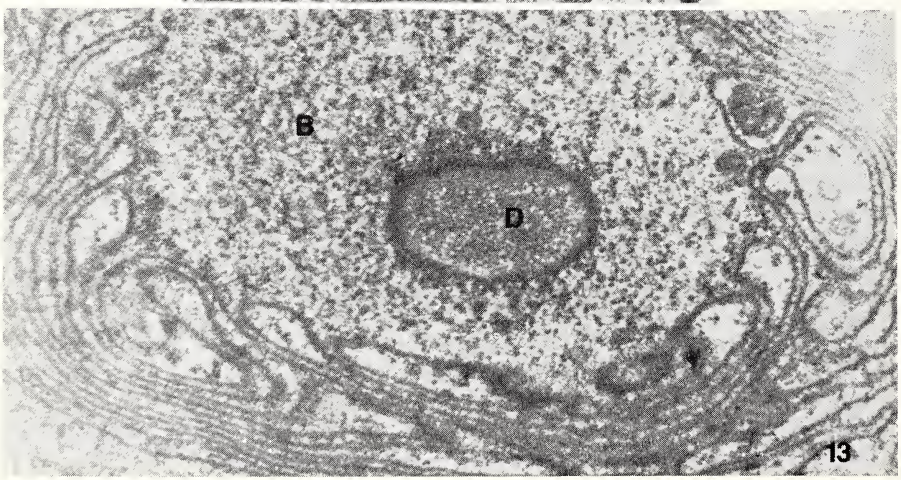
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type A cell, but are usually one-half to two-thirds the size of the latter. The diameter of the microtubules is approximately 500 Å. The diameter of the duct lumen is about 3.5 microns, and the thickness of its cuticular wall is approximately .20 microns. That portion of the type B cytoplasm which surrounds the duct is thrown into concentric swirls of membranes (Figs. 10 & 13). These remarkable swirls become more densely packed toward the end of the duct which is closest to the type A cell (Figs. 10 & 14). Consequently, there is very little type B cytoplasm at this end of the duct, while the granular type A cytoplasm is quite obvious (Figs. 8 & 10). Furthermore, close to this region, the anterior (nucleated) portions of the type A cells fold back upon themselves so that cross-sections through the supracoxal glands reveal cytoplasm of both the type A and type B cells, including the ducts (Figs. 6 & 15).

A fourth pair of cells forms a unit unlike that composed of cell types A and B. This fourth pair includes a secretion unit, or type C cell, that is characterized by its comparatively small size (approximately 12 microns long by 8 microns wide) and its cytoplasm which is replete with a variety of organelles (Fig. 16). The most easily recognized components of the type C cell are the extensive rough endoplasmic reticulum, lysosomes, mitochondria, and single nucleus. However, in the more dorsal aspect of this cell type are numerous vesicles which are bound by basement membrane-like structures and have the appearance of empty cisterns (Fig. 17). A cuticle-lined duct which is a narrow (.50 microns diameter) sinuous tube is found within the duct-producing cell that accompanies the type C cell. This duct-producing, or type D, cell has at least one nucleus and several mitochondria in close proximity to the duct itself (Fig. 18).

The four ducts of the functional units have a point of common attachment from which an anteriorly directed duct passes through the supracoxal sclerite to the outside (Fig. 19). The ducts of the three similar units are wholly contained within the type B cells except for the ends closest to the type A cell.

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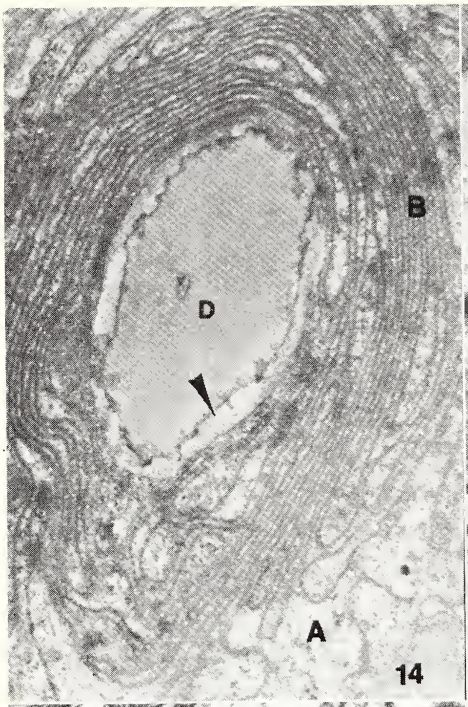
Fig. 10. A diagram of the type B cell (B) with its duct (D). The schematic cross-sections indicate that the cytoplasm is thrown into swirls around the duct, whereas the type B cytoplasm below the duct is highly infolded and contains many peripheral mitochondria. Nucleus (N).

Fig. 11. The cytoplasm of the type B cell (B) is replete with microtubules (arrowheads), many of which are directed along the long axis of the cell. × 9000.

Fig. 12. TEM of a section near the base of the type B cell (B). Numerous infolded membranes and mitochondria (arrowheads) are obvious. Haemocoel (H). × 3500.

Fig. 13. The end of the duct (D) within the type B cell (B) appears to be covered by a porous cap. The peripheral cytoplasm is in swirls. × 7500.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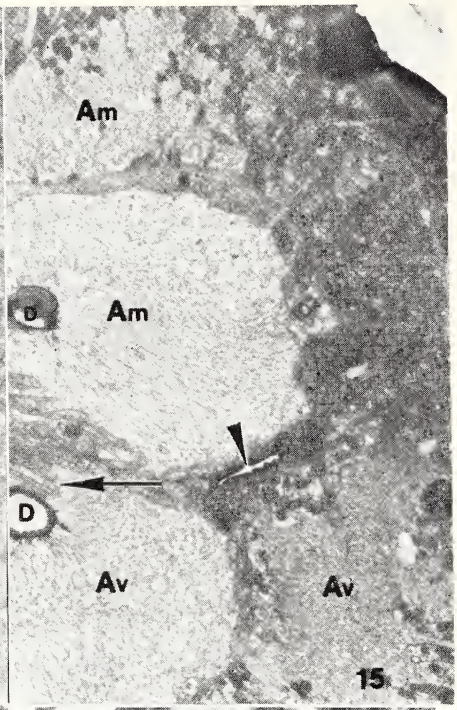
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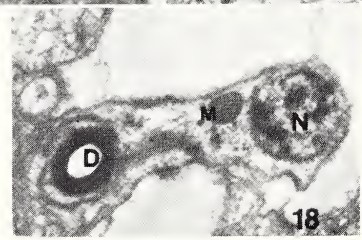
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These duct ends appear as porous caps which communicate with the cytoplasm of the type A cell (Figs. 7, 8 & 15). The opposite end of the duct has an identical porous cap within the cytoplasm of the type B cell (Fig. 13).

Following a description of the components of the supracoxal gland, it is now possible to place these components in their relative spatial positions within the mite. The three similar units are approximately the same size. There is one unit dorsally, one in the middle, and one ventrally, with the type C cell located laterally (Figs. 6 & 19). The dorsal unit is situated so that its cell body is medial to the cell body of the middle unit, but its posterior limit is the most dorsal element of the supracoxal gland (Fig. 6). The portion of the type A cell which folds back upon itself extends in a dorso-medial direction (Fig. 5). The middle unit is also the most lateral of the three and its cell body (of the type A cell) is folded dorsally (Fig. 6). The ventral unit has the cell body of its type A cell directed ventro-laterally so that a part of it protrudes into the coxa of leg I (Figs. 20 & 21).

DISCUSSION

The supracoxal glands of acarid mites have been ascribed several functions such as respiratory (Megnin, 1886), salivary (Lonnfors, 1930), and accessory (Woodring, 1972). This is not surprising when one considers the great morphological variety and diversity of habitat which are encountered among the

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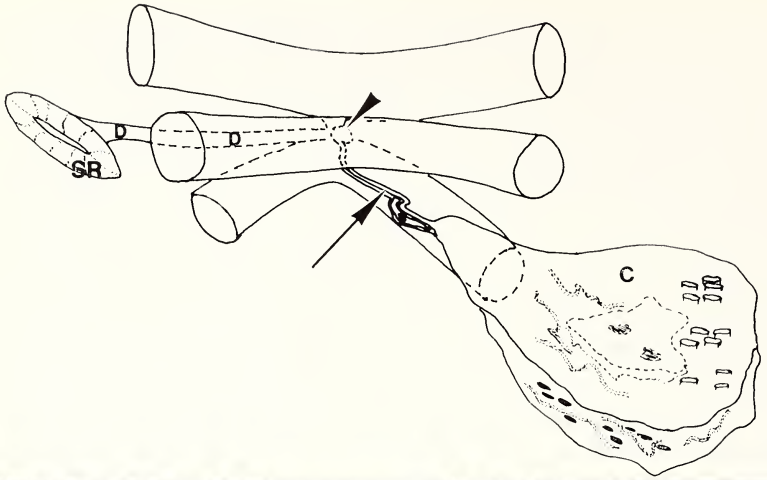
Fig. 14. A cross-section through the middle of the duct (D) demonstrates the remarkable swirls of type B cytoplasm (B) and membranes which surround the duct. The duct is lined by cuticle (arrowhead), and type A (A) cytoplasm envelops the complex. × 7500.

Fig. 15. A cross-section through anterior portions of the medial (Am) and ventral (Av) units of the supracoxal gland reveals the region where the type A cells fold back upon themselves; thus we observe the ducts (D) surrounded mostly by type A cytoplasm (see Fig. 5). One duct is in contact with a few swirls of the type B cell (arrow), and the other duct is partially covered by its porous cap, so no type B cell is apparent. The lateral, external cuticle of the mite is seen in the upper right hand corner of the picture. Also observed at this level is a portion of the narrow duct (arrowhead) which leads to the fourth functional unit. × 3000.

Fig. 16. The secretory cell (type C cell) of the fourth functional unit is characterized by a single nucleus (N), lysosomes (L), and an extensive rough endoplasmic reticulum (arrowheads). The base of a type B cell (B) is nearby. × 9500.

Fig. 17. Portions of the secretory cell seen in Fig. 16 are characterized by apparently empty cisterns (*) surrounded by thick walls. × 9500.

Fig. 18. A narrow, winding duct (D), with its own duct-producing cell (N = nucleus, M = mitochondrion), leads from the secretory cell (type C cell) of the fourth functional unit to a common union with the other ducts (see Fig. 19). × 9500.



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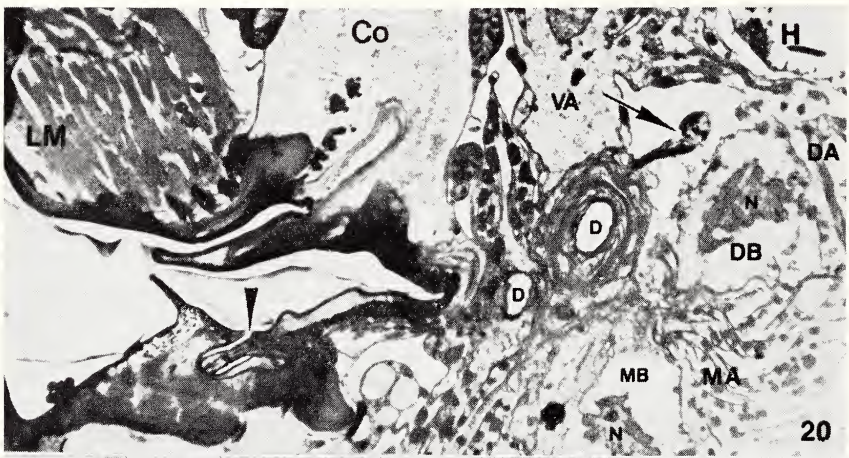

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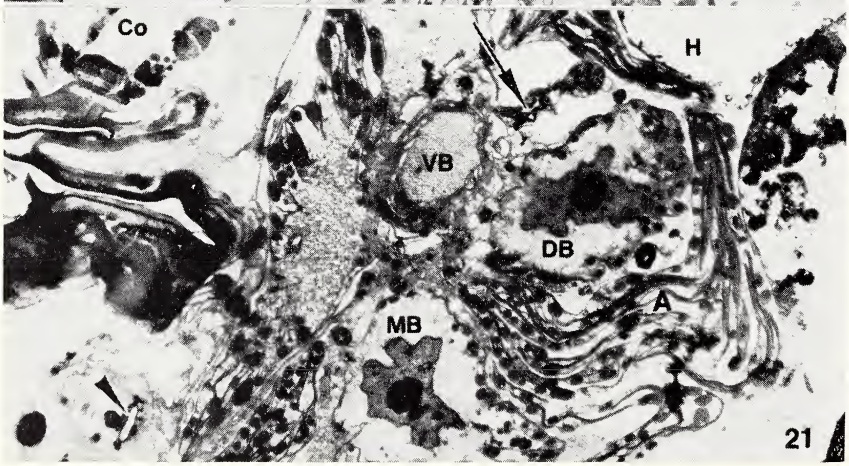

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families of the Acaridei (Acaridia). Thus it is difficult to dismiss any proposed function as impossible.

In the case of *D. farinae*, the supracoxal glands have structural details which are suggestive of a repugnatorial apparatus fashioned after that of several arthropods (Eisner, 1970). These arthropods have reactor glands in which chemical precursors are produced so they can be mixed and subsequently catalyzed at the moment of discharge. The supracoxal glands of *D. farinae* may be constructed to perform in this manner. In each functional unit of the supracoxal gland, two cell types have access to a cuticle-lined duct. (The presence of cuticular ducts is probably a necessity when dealing with potentially noxious products.) Cell type A, with its many mitochondria adjacent to the haemocoel, may concentrate materials from the haemolymph to be secreted in some form through the porous end of the duct (Fig. 9). Cell type B functions as a duct-producing cell and possibly is secretory as well. It is essential to recall that the type C cell communicates with the other cell types at the point of common attachment for the ducts. The type C cell is replete with rough endoplasmic reticulum which may indicate the synthesis of a proteinaceous product, possibly an enzyme. Therefore, if the type B cell has a secretory function, it could secrete its product through the porous cap and

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Fig. 19. A diagrammatic representation of the ducts with the cytoplasm of the three similar units removed. The fourth functional unit (type C cell and duct) is enlarged and pulled laterally out of its normal position between the dorsal and ventral units. All the ducts, including the small narrow duct of the fourth unit (arrow), meet at a common point (arrowhead). An additional duct (D) passes through the cuticle of the supracoxal sclerite to open to the outside through a slit-like orifice surrounded by a sclerotized ring (SR) (see Fig. 3).

Fig. 20. A low magnification TEM of an antero-frontal section through the entire supracoxal gland. At this level, portions of all functional units are observed. To the right of the picture are the fimbriated portions of the type A cells from the dorsal (DA) and medial (MA) units. The nucleated (N) regions of the type B cells are also seen (Dorsal B cell = DB, Medial B cell = MB). The third similar functional unit is sectioned through the level of the duct (D) which is bent (see Fig. 19) so that two of its regions are viewed. This is in the ventral unit which has a portion of its A cell (VA) extending laterally into the coxa of leg I (Co) where leg muscles (LM) are seen. The small duct-producing cell of the fourth unit (arrow) is seen in its usual position between the dorsal and ventral units. An arrowhead marks the external opening of the channel which carries salivary secretions to the buccal cavity (see Fig. 2). Haemocoel (H). × 1500.

Fig. 21. A section ventral to that seen in Fig. 20. All anatomical features are the same except that we are now beyond the level of the ducts, and the swirled cytoplasm of the ventral type B cell (VB) is obvious. The duct (arrow) leading to the type C cell is observed, and the duct of a medial salivary gland (arrowhead) is also seen. Haemocoel (H). × 1500.

into the duct (Fig. 13) to mix with the product of the type A cell, whereupon the two secretions may be catalyzed by an enzyme from the type C cell prior to being discharged to the outside. If the type B cell is strictly a duct-producing cell, then an enzyme from the type C cell may be necessary to dissociate the secretion product (a process described in some arthropods by Eisner, 1970) of the type A cell into some repugnatorial agent. The biochemical and behavioral evidence to support this repugnatorial theory is not clearly available (Wharton & Arlian, 1972).

Several authors (Grandjean, 1937; Hughes, 1959; Hammen, 1968, Prasse, 1968; Woodring, 1972) have described the podocephalic canals of a few acariform mites. This canal is described as a gutter which passes medially and ventrally from the supracoxal sclerite over the dorsal aspects of the palpal coxae to the posterior limits of the pre-buccal cavity. Secretions from salivary glands located within the idiosoma are reportedly dumped into the podocephalic canals to be used pre-orally. Grandjean (1937) describes openings medial to the orifice of the supracoxal glands in an acarid mite, *Otodectes cynotis*. In *D. farinae*, idiosomal salivary glands which release their products into the podocephalic canal have been demonstrated (Brody *et al.*, 1972). This portion of the podocephalic canal is covered by a cuticular flap (Fig. 2) and the salivary duct makes its communication with the podocephalic canal at least 25 microns medial and ventral to the supracoxal gland orifice. In addition to this covered podocephalic canal, there is an open gutter on the supracoxal sclerite of *D. farinae* (Fig. 2), but it is ventral to the gland orifice and appears to merely run along the medial surface of coxa I (Figs. 2 & 4). It is possible that this gutter has been mistaken for the podocephalic canal by some authors.

As an alternative to the repugnatorial function described above, the complex supracoxal glands may be involved in an osmoregulatory process. Several investigators (e.g. Oschman and Wall, 1969) have studied the fine structure of various insect hindguts. The hindgut epithelium, reportedly an integral part of the insect's water balance mechanism, is composed in part of infolded cell membranes with numerous adjacent mitochondria. Electron micrographs of this insect system are strongly reminiscent of structures observed in the periphery of the type A and B cells in the supracoxal glands of *D. farinae* (Figs. 6 & 10). In addition, Woodring (1972) has made a strong case for an osmoregulatory function in the coxal glands of oribatid mites. The fine structural anatomy of oribatid coxal glands has not yet been described. However, consideration of Woodring's suggestion that the coxal glands of all mites are homologous at least in part, along with consideration of structural similarities between the supracoxal glands (of *D. farinae*) and the insect osmoregulatory apparatus, hopefully will stimulate the question of supracoxal gland function into further investigation.

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Terrestrial Mites of New York II. Mites in Birds' Nests (Acarina)[1]

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Abstract: Twenty-one species of mites belonging to eight families are reported found in nests of birds from New York; three are new to science: *Cheiroseius* **hurlbutti** n. sp., *Lasioseius* **tridentatus** n. sp. and *Pellonyssus* **nidicolus** n. sp. The fauna includes important biting and stored products species, and those associated with house-dust allergy. *Tyrophagus longior* (Gervais) (Acaridae) and *Dermatophagoides evansi* (Fain), Hughes & Johnston are the two most common mites found in birds' nests. The male of *Sturnophagoides bakeri* (Fain) is described for the first time. Notes and information on distribution and habitats are provided, together with illustrations of certain species. *Gamasellodes americanus* (Garman) is a new synonym of *Gamasellodes bicolor* (Berlese).

Woodroffe and Southgate (1951) and Woodroffe (1953, 1954) studied the importance of birds' nests as sources of household and stored products pests in Britain and confirmed the existence of such wide-spread natural populations of these pests. The faunal list included important species of mites found in stored cereal products and house dusts, such as *Glycyphagus domesticus* (de Geer) (Glycyphagidae) and *Dermatophagoides* sp. (Pyroglyphidae). The present collection is of interest because, firstly, the bird nest mite fauna has not been investigated in this country, and secondly, the results of this survey confirmed the occurrence in nests of the more important stored products species and those associated with house-dust allergy.

This paper is the second in a series containing descriptions and records of terrestrial mites from New York. It reports 21 species belonging to 8 families of mites found in nests of birds: Glycyphagidae (1 sp.), Acaridae (5

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spp.), Pyroglyphidae (2 spp.), Macronyssidae (3 spp.), Dermanyssidae (1 sp.), Ascidae (7 spp.), Digamasellidae (1 sp.), and Veigaiaidae (1 sp.). Many of the species have not been previously recorded and 3 are new to science. *Tyrophagus longior* (Gervais) (Acaridae) and *Dermatophagoides evansi* Fain, Hughes & Johnston (Pyroglyphidae) are the dominant and most abundant species found in nests of birds.

Abandoned birds' nests were collected during the summer and fall of 1973 on Long Island and in the Mohawk Valley area, New York. Many of the nests were obtained from fruit trees, eaves of buildings and in bird houses. In most cases the nests were not identified. The mites were extracted from the nests by the use of Berlese funnels.

Glycyphagidae

Aeroglyphus robustus (Banks)
(Figures 1–14)

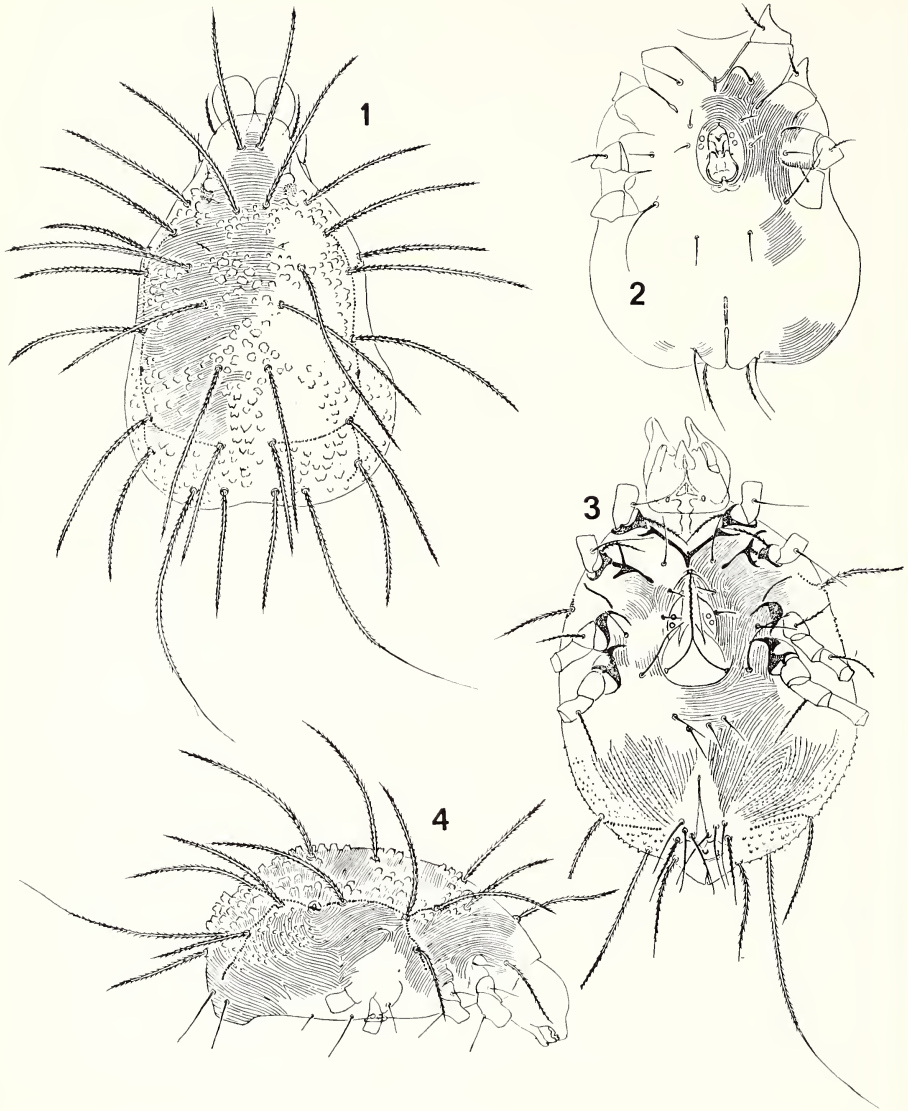
Glyciphagus (sic) *robustus* Banks, 1906, Bur. Entomol. USDA Tech. Ser. 13: 13.

Aeroglyphus robustus, Cooreman, 1959, Bull. Inst. R. nat. Belg. 35: 10.

Remarks. Zakhvatkin (1941) established the genus *Aeroglyphus* for a single species, *Glycyphagus peregrinans* Berlese, 1892, and indicated that *Glycyphagus robustus* Banks, a North American species, could also belong to this genus. The inadequate original description of *robustus* made its generic placement uncertain. Cooreman (1959) re-described and figured *robustus* and placed it in *Aeroglyphus*. Because *robustus* is a wide spread and seemingly important species, we are providing detailed illustrations of both sexes and nymph for easy identification.

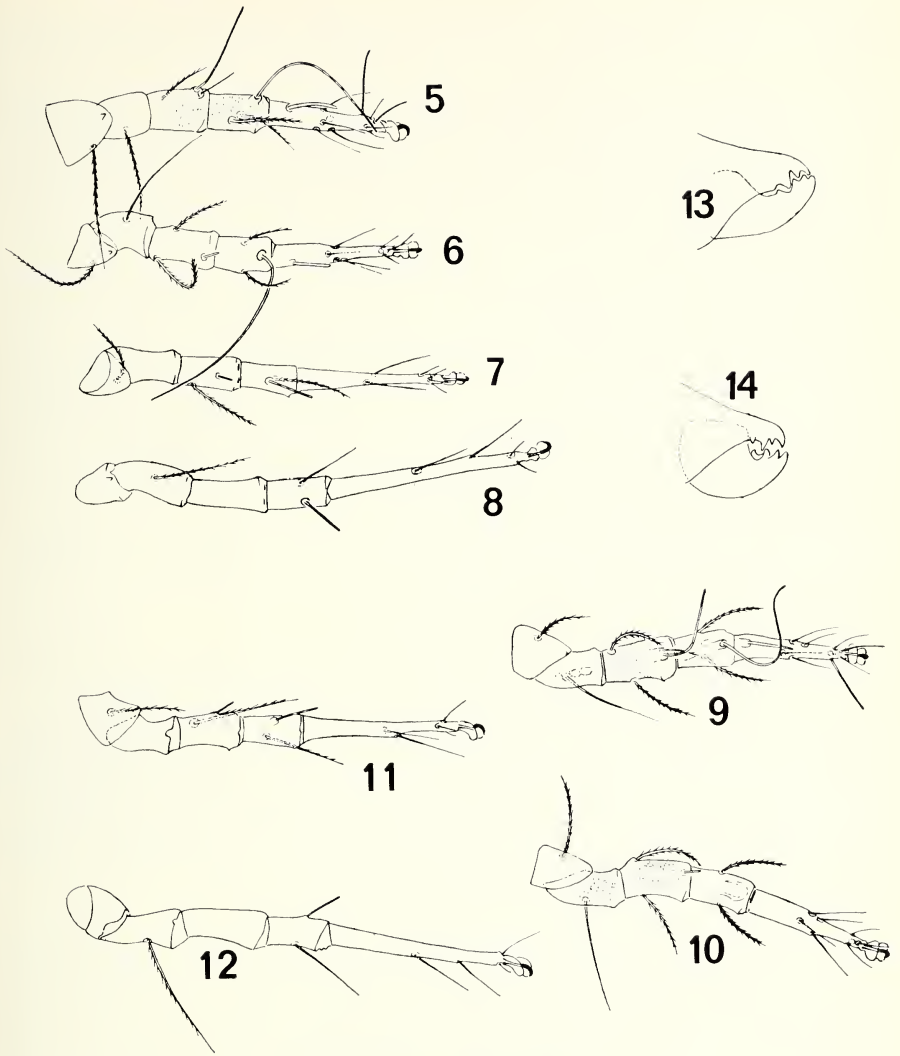
A. robustus is distinguished from *A. peregrinans* (Berlese), the only other species in the genus, by the dorsal ornamentation of the idiosoma which is covered with fine striations and large crenulate tubercles or papillae of varying sizes, and with a row of sawlike teeth laterally connecting setae h_1, he, l_a, l_p, sae and d_4 and continuing ventrally to the anal region; anteriorly this line goes beyond the humeral setae ventrally; all dorsal setae are very long and pectinate. This mite is found in a wide variety of natural habitats. *A. peregrinans* has been found only on the hymenopterous genera *Xylocopa* and *Bombus* in Europe (Zakhvatkin, 1941 (1959); Cooreman, 1959).

Distribution. Aeroglyphus robustus was originally taken "in a lot of seeds" from Ohio. It is now found in a wide variety of habitats and is known to cause itching of human skin. Recorded by Cooreman (1959) from Rensselaerville, New York on a eumenine wasp; our specimens were taken from birds' nests at Saratoga and Helderberg, New York, July 26, 1973, May 18, 1973 (M. Delfinado, coll.), and Stoughton, Massachusetts, August 1, 1974 in nests of birds near house (E. W. Baker & M. D. Delfinado, coll.). The USNM collection contains specimens from Washington, D.C., December



Aeroglyphus robustus (Banks), Figs. 1–14. 1. dorsum of male; 2. venter of male; 3. venter of female; 4. lateral view of nymph; 5. leg I of male; 6. leg II of male; 7. leg III of male; 8. leg IV of male; 9. leg I of female; 10. leg II of female; 11. leg III of female; 12. leg IV of female; 13. chelicerae of male; 14. chelicerae of female.

8, 1958, in ant nest refuse (T. Silvey, coll.); Hunter, North Dakota, November 15, 1948, on barley (Post & Anderson, coll.); Washington, D.C., September 17, 1954, in *G. melonella* culture in bees wax (J. L. Nickel, coll.); Lovain, Ohio, July 1953, in insect trash from window sill (J. Arnold, coll.);



Figs. 1–14. Continued.

Boxford, Massachusetts, August 18, 1961, on Tabanidae trapped in spider web in a garage (no coll.); Mocksville, North Carolina, December 28, 1963, in soybean hay causing itch on person (J. C. Harding, coll.).

Acaridae

Tyrophagus longior (Gervais)

Tyroglyphus longior Gervais, 1844, Hist. nat. Ins. 3: 262.

Tyrophagus longior, Zakhvatkin, 1941, Zool Inst. Acad. Sci. USSR (N. Ser.) 28: 109

(1959:147); Baker and Wharton, 1952, Introd. Acarology: 335; Robertson, 1959, Aust. Jour. Zool. 7: 165.

Remarks. Robertson (1959) reviewed the genus *Tyrophagus* and gave an excellent characterization of *longior*. It is similar to *T. putrescentiae* (Schrank), but the shape of the aedeagus and the pseudostigmatic organ and the arrangement of the postanal setae are distinctive for *longior*; also the first pair of postanal setae in *longior* are very short, not reaching the posterior margin of the idiosoma, whereas these setae are very long in *putrescentiae*.

Distribution. T. longior has been recorded in a wide variety of natural habitats but not in nests. It is found primarily on cheeses in Europe, England, Canada and New Zealand (See Roberston, 1959:167). Baker and Wharton (1952:335) mentioned that *longior* "has been taken occasionally in America". The USNM collection contains specimens from Sand Lake, Oregon, August 26, 1947 (R. W. Every, coll.) in hay; Wilmington, North Carolina, February 19, 1946 (W. M. Kulash, coll.) on chickens and in house. Numerous specimens were taken from all birds' nests at Farmingdale, Long Island, New York, June 30, and July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.). It is the most common mite so far found in birds' nests.

Acarus siro Linnaeus

Acarus siro Linnaeus, 1758, Syst. Nat., Ed. 10, 1: 616; Griffiths, 1964, Bull. Brit. Mus. nat. Hist. Zool. 11: 432,434; Griffiths, 1970, Bull. Brit. Mus. nat. Hist. Zool. 19: 92.

Remarks. A. siro is the well-known flour mite. According to Griffiths (1964: 458) *A. siro* appears to be the dominant species within stored products living on processed cereals as well as whole grains, and he believes that many published records of the occurrence of *A. siro* in natural habitats may be based on misidentifications. For clarification of this species see Griffiths (1964, 1970).

Distribution. A. siro is found in stored grain, feed and grain dust in Washington, Oregon and New York and in cheese in Wisconsin; it has been taken on various stored products in Europe, Canada and Chile; it is also recorded from England in house martins' nests. Our specimens were taken in birds' nests at Farmingdale, Long Island, New York, June 30, 1973 (M. Abbatiello & M. D. Delfinado, coll.).

Schwiebia talpa Oudemans

Schwiebia talpa Oudemans, 1916, Entomol. Bericht. 4: 265, Hughes, 1957, Proc. Zool. Soc. Lond. 129: 293; Woodring 1966, Proc. Louisiana Acad. Sci. 29: 96.
Schwiebia pachyderma Zakhvatkin, 1941, Zool. Inst. Acad. Sci. USSR (N. ser.) 28: 203 (1959: 276).

Remarks. Hughes (1957) established the identity of *S. talpa* which is apparently a variable species. The females in the present collection show variation in the size of the dorsal propodosomal plate; the epimeres III-IV are free except in one specimen in which they

are fused with each other as in figure 3 of Hughes (1957:295); usually only one solenidion arises from genu I; in other specimens genu I have 2 solenidia. We have not seen the male of *S. talpa*. For other details on this species see Hughes 1957).

Distribution. This species, tentatively identified as *talpa* by Woodring (1966: 108) has been found in Hawaii, Oregon, Mexico and Brazil on plants, seeds, roots and bulbs; Pillai & Winston (1963:53) found it in decaying plants and sod in Colorado. It has also been collected in soil and litter in Europe. We found 7 females in birds' nests at Farmingdale, Long Island, New York, June 30, 1973 (M. D. Delfinado & M. Abbatiello, coll.).

Schwiebia sp. probably *mertzis* Woodring, 1966.

A specimen from a bird's nest at Farmingdale, Long Island, New York is probably this species, but it is difficult to be certain on the basis of single, poor specimen. As in *mertzis* it lacks seta d_3; *ba* on tarsus I is a large conical spine; genu I has 2 large spines, that is seta MG is a conspicuous stout spine as is cG.

Caloglyphus sp.

Only the hypopial forms were found in the nests of birds at Farmingdale, Long Island, and they are probably an undescribed species.

Pyroglyphidae

Dermatophagoides evansi Fain, Hughes & Johnston

Dermatophagoides evansi Fain, Hughes & Johnston *in* Fain, 1967a, Acarologia 9: 205.

Remarks. The female of *D. evansi* is distinguished from other members of the genus by the bulbous structure of the bursa copulatrix, and only the dorsal propodosomal plate is present; the male has both propodosomal and hysterosomal plates. For detailed description and figures of the species see Fain (1967a); van Bronswijk and Sinha (1971) gave a pictorial key for the identification of the species of the genus.

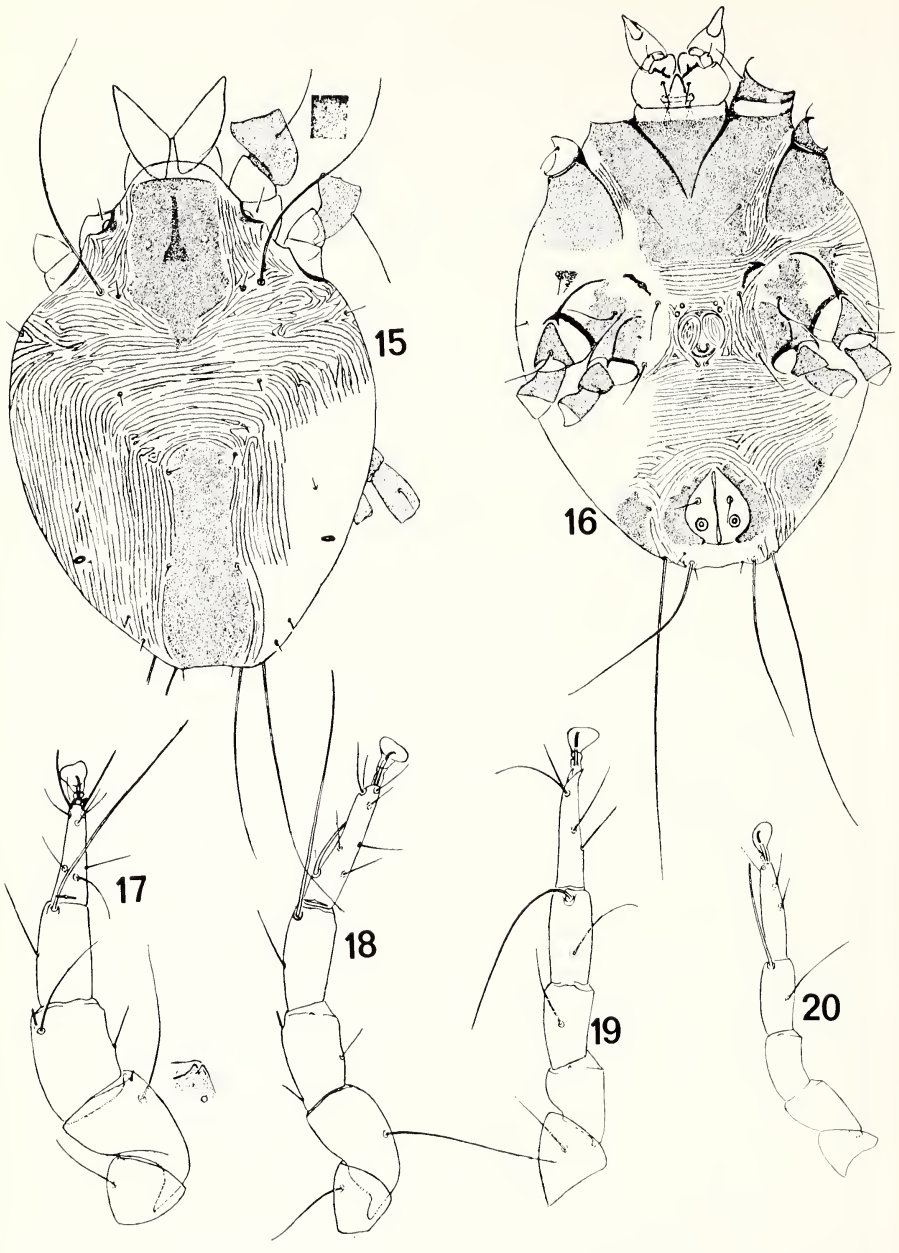
Distribution. The types of *D. evansi* were taken in feather pillows in England. Other specimens were found in a bird's nest (Icteridae) from Ohio, and nest of cave swallow in New Mexico. Our material was taken from all unknown birds' nests at Helderberg, New York, May 18, 1973 (M. D. Delfinado, coll.). It is the most common pyroglyphid mite found in birds' nests in New York. Wharton (1970) reported *evansi* in a house dust sample (no specific locality was given).

Sturnophagoides bakeri (Fain)

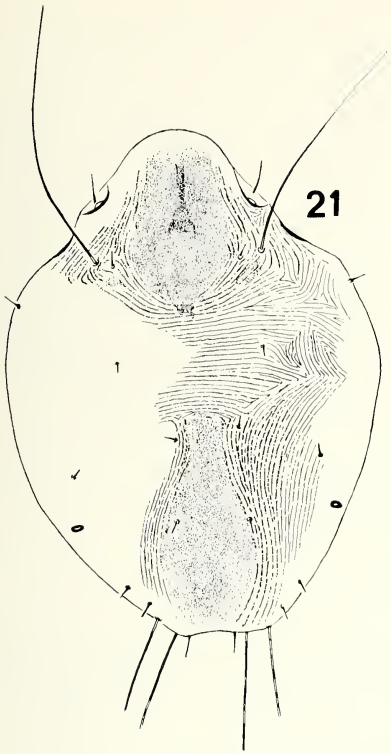
(Figures 15–25)

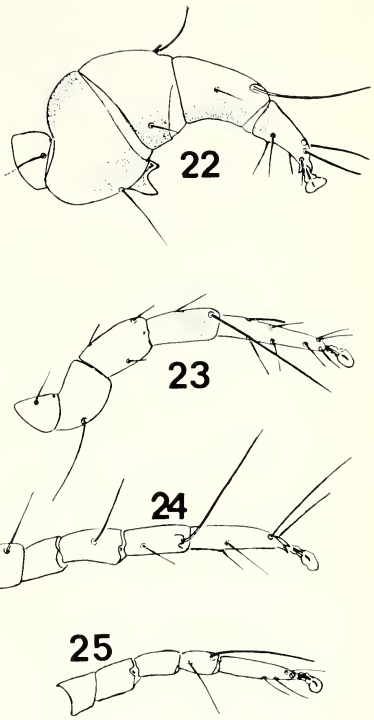
Dermatophagoides (*Sturnophagoides*) *bakeri* Fain, 1967a, Acarologia 9: 215.
Sturnophagoides bakeri, Fain, 1967b, Acarologia 9: 870,876; van Bronswijk and Sinha, 1971, Jour. Allergy 47: 52.

Remarks. Only the female has been described and figured for this species. The present collection contains both sexes found in nests of birds.



Sturnophagoides bakeri (Fain), Figs. 15–25. 15. dorsum of normal male; 16. venter of normal male; 17. leg I of normal male; 18. leg II of normal male; 19. leg III of normal male; 20. leg IV of normal male; 21. dorsum of heteromorphic male; 22. leg I of heteromorphic male; 23. leg II of heteromorphic male; 24. leg III of heteromorphic male; 25. leg IV of heteromorphic male.





Figs. 15–25. Continued.

Male. Similar to female in having both dorsal prodosomal and hysterosomal plates present; scapular external setae not situated on sclerotized platelets. *S. bakeri* may be distinguished from other species in the genus by the shape of the dorsal plates, leg chaetotaxy and solenidiotaxy. Leg I in heteromorphic form with enlarged femur and genu and strong dentate lateral process on femur (figs. 21–25); in normal form leg I (figs. 15–20) small, not enlarged and similar to that of female, but with small dentate process on femur; also shapes of dorsal plates of this form differ slightly from those of the heteromorphic male. Chaetotaxy of legs I–IV of heteromorphic male (figs. 21–25): trochanters- 1, 1, 1, 0; femora- 1, 1, 0, 0; genua- 2, 3, 1, 0; tibiae- 1, 1, 1, 1; tarsi- 4, 7, 4, 3 (in normal form tarsus I possesses 6 setae); solenidiotaxy: genua- 1, 0, 0, 0; tibae- 1, 1, 1, 1 (all very long); tarsi- 2, 1, 0, 0. Tarsi I & III of both forms ending in bifid clawlike organs; tarsi IV each with small suctorial disc.

Distribution. This species was previously known from Virginia on starlings. Our collection contains specimens from Helderberg, New York, May 6 & 18, 1973, found in unidentified birds' nests (M. D. Delfinado), coll.); Stoughton, Massachusetts, August 1, 1974, found in birds' nests (M. D. Delfinado & E. W. Baker, coll.).

Macronyssidae

Ornithonyssus sylviarum (Canestrini & Fanzago)

Dermanyssus sylviarum Canestrini & Fanzago, 1877, Atti Ist. veneto 5: 124.
Ornithonyssus sylviarum, Sambon, 1928, Ann. trop. Med. Parasit. 22: 105; Baker, et al., 1956, Tech. Publ. Nat. Pest Cont. Assoc.: 26.
Macronyssus sylviarum, Zumpt & Till, *in* Zumpt, 1961, S. Afr. Inst. Med. Res. Publ. 1: 47.

Remarks. This mite is a serious pest of domestic fowl. In the absence of its normal hosts it will attack man causing itching. Encephalitis viruses (St. Louis and Western equine) have been isolated from specimens of *sylviarum* taken from wild bird nests (Hammon, et al., 1948). For further details see Baker, et al. (1956). *D. sylviarum* is similar in general appearance to *bacoti* (Hirst) and *bursa* (Berlese), but the dorsal chaetotaxy and shape of the dorsal plate are distinctive for *sylviarum*; also the sternal plate of *sylviarum* has 2 pairs of setae, the third pair being located posterior to the plate. There are always 3 pairs of setae on the sternal plate of *bacoti* and *bursa*.

Distribution. This species occurs throughout the temperate regions of the world on domestic fowl and many wild birds. Specimens in the present collection were taken in an oriole's nest at Delmar, New York, April 13, 1973 (M. D. Delfinado, coll.).

Pellonyssus **nidicolus** n. sp.
(Figures 26–28)

Female. Length of body 542 μ; width 255 μ. Chelicerae very long and slender as shown in figure 28. Sternal plate very narrow, with faint striate pattern, 3 pairs of setae, the first pair shortest. Metasternal setae absent. Genital plate tapering to a point, with faint striate and reticulate pattern. Anal plate large, elongate, narrowing posteriorly and probably folded distally; anus situated at anterior ⅓ of the length of anal plate; para-anal setae posterior margin of anus. All ventral and marginal setae on integument of idiosoma uniformly long and strong. Peritremes reaching about middle of coxa II. Dorsal plate divided between coxae III & IV, each piece large and covering entire body, with straight contiguous margins, indistinct striate pattern, margin of anterior plate indistinct. All dorsal setae uniformly long and strong. Chaetotaxy as in figure 26. Legs typical for the genus; coxal spur formula: 1-2-2-1.

Male. Unknown.

Holotype. A single female, Farmingdale, Long Island, New York, June 30, 1973, in a bird's nest (M.D. Delfinado & M. Abbatiello, coll.). Deposited in New York State Museum & Science Service, Albany.

Remarks. P. nidicolus is distinguished from all other species of *Pellonyssus* by the large, contiguous dorsal plates bearing uniformly long and strong dorsal setae; large anal plate, and uniformly long and strong ventral setae on the integument of idiosoma.

Dermanyssidae

Dermanyssus gallinae (de Geer)

Acarus gallinae de Geer, 1778, Mém. Hist. Ins. 7: 111.
Dermanyssus avium Dugés, 1834, Ann. Sci. nat. (Zool.) 1: 18 (*nom. nud.*, see Oudemans, 1936: 308).

Dermanyssus gallinae, Evans & Till, 1962, Ann. Mag. nat. Hist. (13) 5: 283; Evans & Till, 1966, Bull. Brit. Mus. nat. Hist. Zool. 14: 350; Moss, 1968, Jour. Med. Entomol. 5: 78,84.

Remarks. This species has been adequately described and figured by Evans & Till (1962, 1966) and Moss (1968), and a comprehensive account was provided by Baker, et al. (1956). *D. gallinae* is primarily an avian parasite of world-wide distribution. It is commonly recorded on domestic fowl, turkey, duck, pigeon, sparrow, starling and canary; and in the absence of its normal hosts it will attack mammals and man causing skin irritation.

Distribution. Cosmopolitan. Our specimens were taken in nests of birds from Stoughton, Massachusetts, August 1, 1974 (M. D. Delfinado & E. W. Baker, coll.); Albany, New York, July 23, 1973, in bird's nest on window sill (no coll.).

Hirstionyssus utahensis Allred & Beck

Hirstionyssus utahensis Allred & Beck, 1966, Brigham Young Univ. Sci. Bull. 8: 22.
Hirstionyssus (*H.*) *utahensis*, Herrin, 1970, Jour. Med. Entomol. 7: 419.

Remarks. The re-descriptions and figures of *H. utahensis* by Herrin (1970) are adequate for its identification. The characteristic feature of this species is the presence of stout and clawlike setae on tarsus II. Tarsus IV lacks spiniform setae. Coxal spur formula is as follows: 0-2-2-1.

Distribution. H. utahensis is common and widely distributed in the United States on small mammals (Herrin, 1970). A series of specimens was taken in the nests of birds at Helderberg, New York, May 18, 1973 (M. D. Delfinado, coll.).

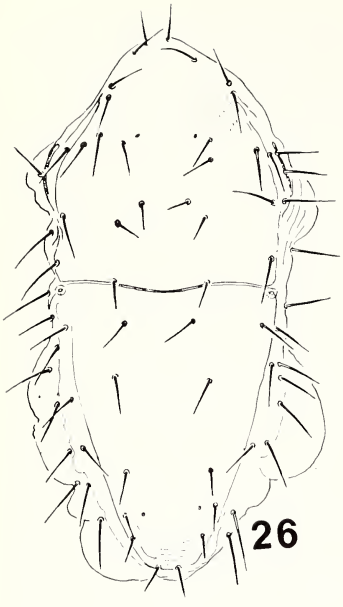
Ascidae

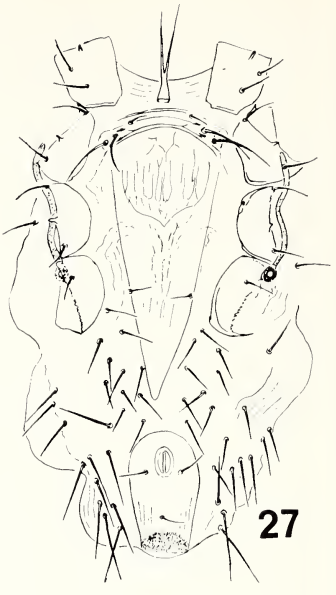
Asca aphidioides (Linnaeus)

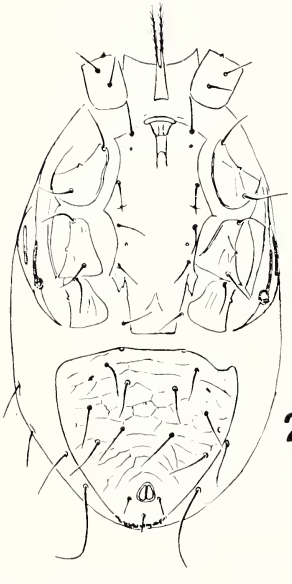
Acarus aphidioides Linnaeus, 1758, Syst. Nat., Ed. 10,1: 758.
Asca aphidioides, Ryke, 1961, Zool. Anz. 167: 127; Hurlbutt, 1963, Acarologia 5: 484.

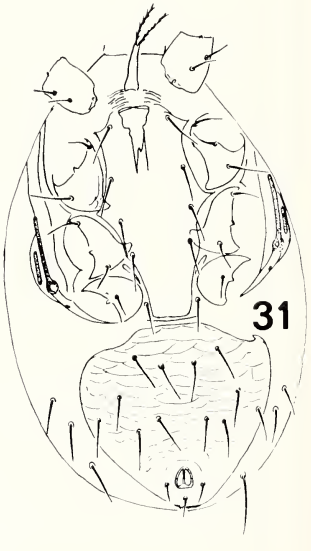
Remarks. Hurlbutt (1963:484) gave an excellent review of A. *aphidioides*. It most closely resembles *A. garmani* Hurlbutt by the presence of one pectinate seta on the posterior tubercle, the tridentate tectum and the strong pectinate setae on the dorsal plate, but the polygonal ornamentation of the dorsal plate is distinctive for *aphidioides*.

Distribution. It is common in forest litter in eastern United States, Nebraska, Missouri, Canada and Hawaii; and it is widespread in Europe. *A. aphidioides* has also been reported in *Peromyscus* nests in Maryland (Hurlbutt, 1963: 488). We found a single female in a bird's nest at Farmingdale, Long Island, New York, June 30, 1973 (D. M. Delfinado & M. Abbatiello, coll.).









Pellonyssus nidicolus, n. sp., Figs. 26–28. 26. dorsum of female; 27. venter of female; 28. chelicerae of female.

Blattisocius keegani Fox, Figs. 29–30. 29. venter of male; 30. chelicerae of male.

Blattisocius tarsalis (Berlese), Fig. 31. venter of male.

Asca nesioca Athias-Henriot

Asca nesioca Athias-Henriot, 1961, Acarologia 3: 463; Hurlbutt, 1963, Acarologia 5: 497.

Remarks. This species is distinguished by having two simple setae on each posterior tubercle, simple dorsal setae and tridentate tectum. Hurlbutt (1963:499) separates *A. nesoica* from the closely related *A. nova* Willman by the V-shaped notch on the anterior margin of the sternal plate, and arrangement of setae on the posterior dorsal plate.

Distribution. It is found in orchard soil and sod in Connecticut, Maryland, West Virginia, Oregon and in moss in Europe. A single female was taken in a bird's nest at Farmingdale, Long Island, New York, July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.).

Blattisocius keegani Fox

(Figures 29–30)

Blattiosocius (sic) *keegani* Fox, 1947, Ann. Entomol. Soc. Amer. 40: 599.
Blattisocius keegani, Cunliffe & Baker, 1953, Pinellas Biol. Lab. Publ. 1: 7; McGraw & Farrier, 1969, N.C. Agric. Expt. Sta. Tech. Bull. 192: 55.
Melichares (*Blattisocius*) *keegani* Evans, 1958, Proc. Zool. Soc. Lond. 131: 209.

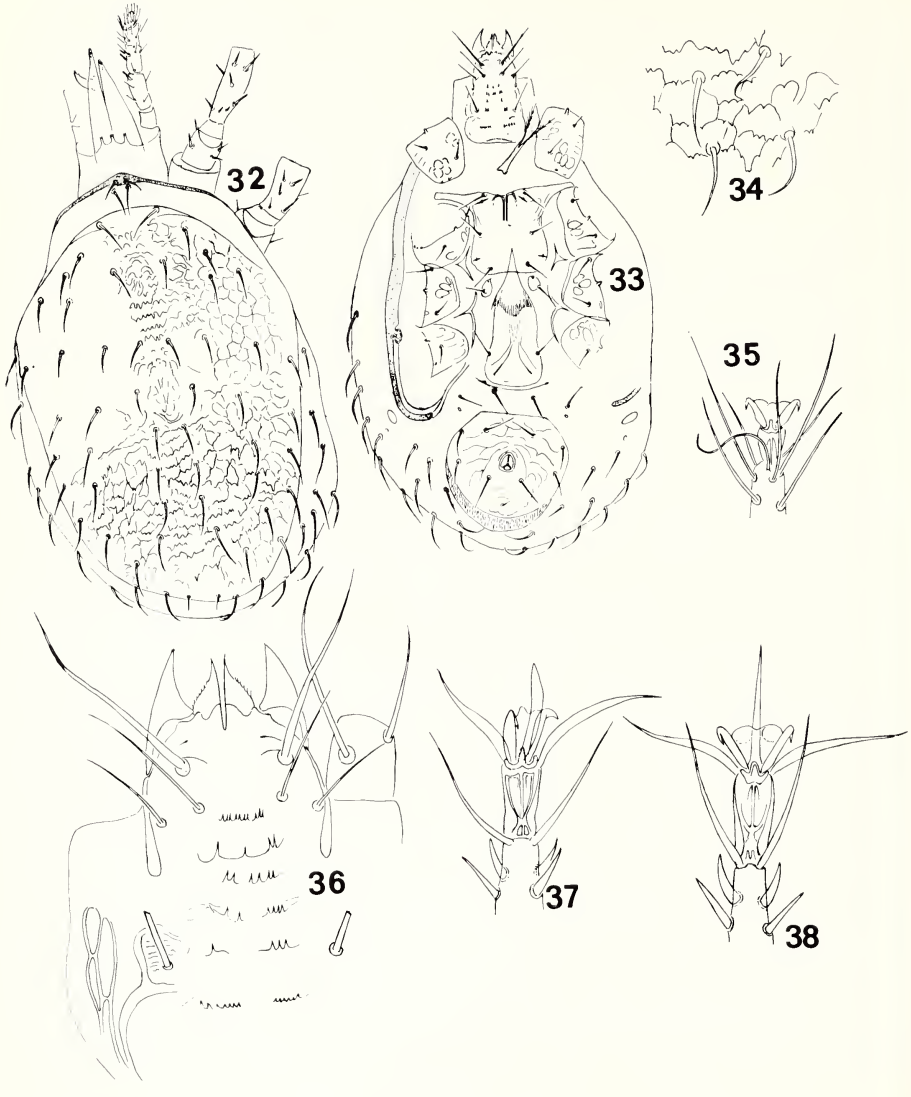
Remarks. B. keegani is immediately distinguished, in both sexes, by the long unidentate movable digit of the chelicerae, and very short peritreme which extends to about the middle of coxa III; in the male, the peritreme is accompanied distally by a small secondary peritreme as in figure 29 (accessory organ of Treat, 1966, figs. 3 & 4). We have seen the same structure in male *tarsalis* (Berlese), but it is situated laterad of the stigmata (fig. 31). Also, the male *keegani* has 5 pairs of long preanal setae on the ventroanal plate instead of 6 pairs as figured by McGraw & Farrier (1969).

Distribution. The female holotype was taken on *Rattus norvegicus* from Puerto Rico. Specimens have also been taken on rose in Mexico; on citrus and in *Neotoma* nest in Texas; in insect cultures in California, Delaware and Kentucky (Cunliffe & Baker, 1953); on *Ips* spp. in North Carolina (McGraw & Farrier, 1969), and in stored food products infested with various insects (Evans, 1958). The present collection contains a series of both sexes from nests of birds at Helderberg, New York, May 18, 1973 (M. D. Delfinado, coll.).

Cheiroseius **hurlbutti**, n. sp.

(Figures 32–38)

Female. Body length 574 μ, width 434 μ. Anterior gnathosomal (rostral) setae enlarged, lanceolate distally; internal palptrochanter seta long, whiplike; 6 rows of deutosternal teeth as figured, deutosternal groove lacking. Tectum trispinate with serrated tips. Movable digit of chelicerae bidentate; fixed digit with minute teeth medially. Corniculi stout, slightly convergent. Tritosternum with narrow, slender base, pilose laciniae. Sternal plate well sclerotized, with anterolateral margins extending between coxae I & II, anteromedian pair of lobes, 3 pairs of setae subequal in length. Metasternal setae on platelets. Genital plate with one pair of setae. Integument between genital and ventroanal plates with



Cheiroseius hurlbutti, n. sp., Figs. 32–38. 32. dorsum of female; 33. venter of female; 34. detail of dorsal reticulation; 35. empodium and claws of tarsus I; 36. venter of gnathosoma; 37. empodium and claws of tarsus II; 38. empodium and claws of tarsus IV.

4(?) indistinct platelets. Ventroanal plate striate in its anterior ⅔, about as broad as long, with 3 pairs of preanal setae; 2 para-anal setae inserted below anus, about 2½ times longer than postanal setae. Peritremes extending anterad to vertical setae, and tapered posteriorly below its origin at stigmata as far as metapodals. Peritrematal-exopodal plate broad beside and encircling posterior half of coxa IV; endopodals present

as narrow strips between coxae III & IV, II & III. Legs as for the genus; tarsi II–IV with median lobe of pulvillus slender, lanceolate as in figures 37, 38. Dorsal plate well sclerotized, reticulate-denticulate (fig. 34); all setae simple, pointed; each seta borne on a tubercle; chaetotaxy as figured, with 5 pairs of simple setae in the J series.

Male. Unknown.

Holotype. A unique female, Farmingdale, Long Island, New York, June 30, 1973, taken in a bird's nest (M. D. Delfinado & M. Abbatiello, coll.). Deposited in the New York State Museum & Science Service, Albany.

Remarks. The structures of the peritremes and pulvilli of tarsi II–IV, and the ornamentation of the dorsal plate are distinctive for this species. This mite is named for Dr. H. W. Hurlbutt of West Virginia University, Morgantown, West Virginia.

Arctoseius cetratus (Sellnick)

(Figures 39–42)

Lasioseius cetratus Sellnick, 1940, Göteborgs Vetensk.-Samh. Handl. (5). 6B: 99; Schweitzer, 1949, Res. Rech. Scient. Parc. Nat. Suisse 2 (n.s.): 53; Evans, 1958, Proc. Zool. Soc. Lond. 131: 186.

Arctoseius bispinatus Weis-Fogh, 1947, Nat. Jutlandica 1: 225.

Remarks. The characteristic features of *cetratus* are the bispinate tectum and the short peritremes which extend as far as the middle of coxae II. The specimens from Long Island fit the descriptions and figures of this species given by Evans (1958) except for the slightly broadened sensory setae on tarsus I and the variably shaped anal plate. In the specimens from Iceland (type locality) the sensory setae on tarsus I are not enlarged.

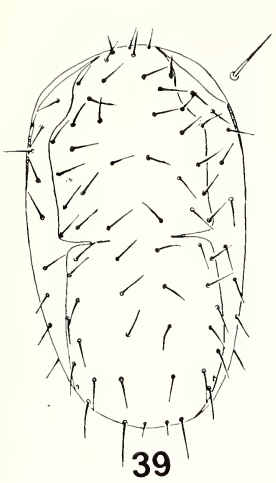
Distribution. A. cetratus has been recorded from Iceland, Denmark, Switzerland, and England, presumably found in soil. Females were taken in birds' nests at Farmingdale, Long Island, New York, July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.). Lindquist (1961:335) listed "North America" under its known distribution.

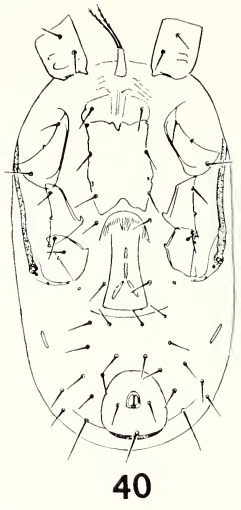
Lasioseius **tridentatus** n. sp.

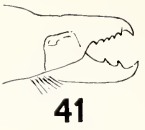
(Figures 43–48)

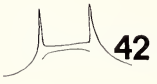
Female. Body length 421 μ, width 319 μ; shield 223 μ wide. Tectum trispinate, with serrated tips as figured. Fixed digit of chelicerae with 12 strong uniform-sized teeth; movable digit tridentate. Corniculi strong, parallel distally; gnathosomal (rostral) setae simple. Sternal plate punctate, with 3 pairs of setae, the first pair of setae situated outside the plate as figured. There is indication of sclerotization anterior to sternal plate. Metasternal setae on platelets; genital plate with 2 setae. Integument between genital and ventroanal plates with 4 platelets. Ventroanal plate reticulate-striate, with 4 pairs of preanal setae; 3 pairs of setae on integument beside plate. Peritrematal-exopodal plate narrow beside coxa IV; endopodals small between coxae III & IV. Peritremes extending anterad to vertical setae. Dorsal plate well sclerotized, reticulate; all dorsal setae except J_5 strong, serrate or serrate-lanceolate distally; J_5 small, simple; chaetotaxy as shown in figure 43, with 5 pairs of setae in dorsal J series. Legs as for genus, with pretarsi and small, rounded pulvilli.

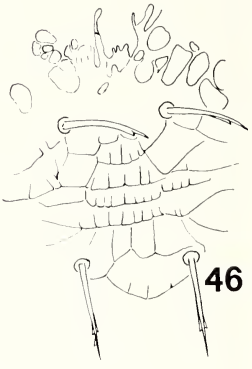
Male. Unknown.

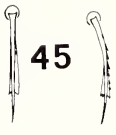


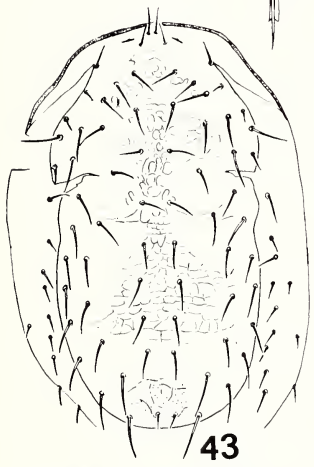


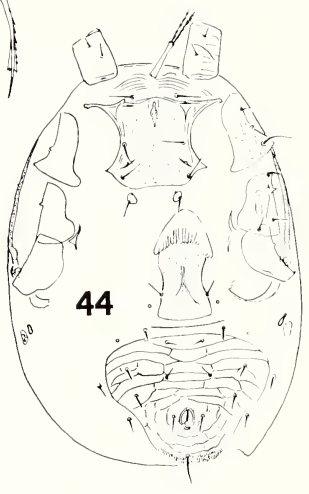


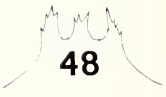












Arctoseius cetratus (Sellnick), Figs. 39–42. 39. dorsum of female; 40. venter of female; 41. chelicerae of female; 42. tectum of female.

Lasioseius tridentatus, n. sp., Figs. 43–48. 43. dorsum of female; 44. venter of female; 45. dorsal body setae of female; 46. detail of dorsal reticulation; 47. chelicerae of female; 48. tectum of female.

Holotype. Female, Farmingdale, Long Island, New York, July 7, 1973, in a bird's nest (M. D. Delfinado & M. Abbatiello, coll.). Deposited in the New York State Museum & Science Service, Albany. Three female paratypes with the same data as the holotype. Two paratypes will be deposited in U.S. National Museum collection.

Remarks. L. tridentatus is similar to *ometes* (Oudemans) by having the digit of the chelicerae tridentate and 4 pairs of preanal setae on the ventroanal plate, but the structure of the tectum and sternal plate is distinctive for *tridentatus*.

Gamasellodes bicolor (Berlese)

Gamasellus (*Digamasellus*) *bicolor* Berlese, 1918, Redia 13: 135.
Digamasellus circuliformis Leitner, 1949, Zbl. Gesamtgeb. 3: 59.
Gamasellodes major Athias-Henriot, 1961, Acarologia 3: 486.
Digamasellus shealsi Costa, 1962, Ann. Mag. nat. Hist. (13) 4: 486.
Iphidozercon bicolor Hirschman, 1962, Acarologie 5: 46.
Leioseius bicolor Bernhard, 1963, Beitr. Syst. Okol. Mitteleur. Acarina 2: 105.
Gamasellus americanus German, 1948, Conn. Agric. Expt. Sta. Bull. 520: 9; Hurlbutt, 1970, Acarologia 7: 475 (as *Gamasellodes* (*bicolor*) *americanus*). *New synonymy* by Hurlbutt (pers. comm.).
Gamasellodes bicolor, Hurlbutt, 1970, Acarologia 7: 474.

Remarks. According to Hurlbutt (pers. comm.) this species has been mistaken for a *Digamasellus* by some workers, but it is an ascid rather close to *Leioseius* and *Asca*. As in other ascids, the metasternal setae arise from the membrane; the circular ventroanal plate is very characteristic.

Distribution. G. bicolor appears to be a widely distributed mite in Europe; it has been collected from mole rat nests in Israel (as *shealsi*); and from orchard sod and bark of apple trees in Connecticut. We found this species to be a common ascid mite in nests of birds at Farmingdale, Long Island, New York, June 30 & July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.).

Digamasellidae

Digamasellus sp. nr. *neocornutus* Hurlbutt, 1967.

Remarks. A single female found in a bird's nest collected from Farmingdale, Long Island, New York, July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.) is probably *neocornutus*, but in the absence of male specimens the identity is uncertain.

Veigaiaidae

Veigaia sp. nr. *mitis* (Berlese), 1916.

Remarks. The single female in a bird's nest collected at Farmingdale, Long Island, N. Y. July 14, 1973 (M. D. Delfinado & M. Abbatiello, coll.) is probably *mitis*, differing only in size. Our specimen is much smaller than those we have examined in the USNM collection, the length of the idiosoma being 446 μ. The type of *mitis* is 508 μ long; specimens from Maryland are 500–530 μ long (Hurlbutt, 1965:606).

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Redescription of *Apochthonius moestus* (Banks), Type of the Genus *Apochthonius* Chamberlin (Pseudoscorpionida, Chthoniidae)

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Abstract: *Apochthonius moestus* (Banks) is redescribed from the holotype female and from numerous specimens taken in and near the type locality, Ithaca, New York. The species seems to be restricted to western New York and adjacent parts of northern Pennsylvania.

Chthonius moestus was described by Banks (1891) from specimens collected at Ithaca, New York, and preserved and studied in alcohol. It was designated as the type of the new genus *Apochthonius* by Chamberlin (1929a), who also published a brief supplementary diagnosis of the species based upon study of new material, mounted on slides, from Washington, D.C. and Missouri, as well as from New York. At that time Chamberlin noted that "this seems to be a somewhat variable species" (p. 67). Subsequent workers (Hoff, 1956, 1958; Lawson, 1968; Nelson, 1975) have placed most eastern and some western epigean specimens of *Apochthonius* in this single species, *A. moestus*. Consequently, the geographic range is said to extend throughout the eastern and central states, and as far west as New Mexico. Specimens from this extensive range, however, only roughly conform to a common pattern. For example, Hoff has described the teeth of the chelal fingers as "contiguous and uniform in size and shape" (1944, p. 125) and has illustrated the teeth in this form for specimens from Illinois (1949, Fig. 15) and from New Mexico (1956, Fig. 1). Lawson (1968), on the other hand, in his doctoral thesis on pseudoscorpions of the southeastern states, illustrates the chela with several of the teeth slightly longer than the majority. Although this discrepancy might seem insignificant, it becomes important when it is recognized that certain western species of the genus may be partially distinguished on the basis of tooth form. A second area of confusion is the lack of agreement in the literature concerning the limits of variation of palpal size and proportions. Lawson

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recently (1968) supported Hoff's observation (1945) that the length/width ratios of femur and chela reported by Chamberlin (1929a) differed from those of specimens from Illinois and North Carolina. While Lawson's specimens from the southeastern United States conform to the limits found by Hoff, they fall near the upper limit of the range. Although most measurements given for length of the male palpal femur are between 0.30 and 0.50 mm, Schuster (1966), without citing any locality data, characterized males of *A. moestus* as having the palpal femur in the range of 0.53–0.58 mm. This situation has developed because most of the morphological characters have never been adequately described. As subsequent authors have determined material obtained far from the type locality, increasing numbers of exceptions to presumed diagnostic characters of the species have been recognized in order to accommodate these additional "*moestus*-like" specimens.

Interest in understanding the real nature of *A. moestus* (Banks) was developed independently by the two authors of this paper. One of us (WBM) has become increasingly frustrated when trying to compare new cavernicolous forms of *Apochthonius* with the type species of the genus. And the other (EMB) recently found at Steens Mountain, Harney County, Oregon, a "*moestus*-like" female which she found impossible to place accurately in view of the confusing descriptions of *A. moestus* in the literature. To both of us, the obvious course of action was to redescribe the species in detail. Fortunately, EMB had discovered the holotype female of *Chthonius moestus* Banks in the J. C. Chamberlin Collection of Pseudoscorpions housed at Pacific University, Forest Grove, Oregon, and WBM had collected a number of specimens of *Apochthonius* from the vicinity of Ithaca, New York. Thus, a redescription of *Apochthonius moestus* is possible, based upon reexamination of the holotype as well as detailed study of specimens collected recently near the type locality.

Family Chthoniidae Hansen

Tribe Chthoniini Chamberlin

Genus *Apochthonius* Chamberlin

Apochthonius Chamberlin, 1929a, p. 66; 1929b, p. 152 (part); Beier, 1932, p. 41 (part); Hoff, 1949, p. 434; 1956, p. 2; Benedict and Malcolm, 1973, p. 621.

The diagnosis of the genus presented by Benedict and Malcolm is generally satisfactory, but one or two minor corrections and additions must be made.

Diagnosis (revised): With the characters of the family Chthoniidae. Palpal chela with setae *ib* and *isb* transversely paired on dorsum of hand proximad of middle; *isb*, *esb* and *eb* closely clustered on base of fixed finger; *it* and *est* closely paired and distad of middle of finger; *et* close to diploid setae at distal end; movable finger with *b* subbasal, *t* and *st* close together and just distad of middle, and *sb* more or less midway between *b* and *st*, sometimes closer to one than to the other. Marginal teeth of chelal fingers well-developed, contiguous; movable finger with a small, rounded sensillum on external surface near dental row, usually slightly proximal to level of *st*. Each coxa I with 3 (rarely 2) simple

setae ("coxal spines") on the face, each such seta originating from a socket in the posterior half of a low, elongate ridge, the anterior end of which is usually produced into a distinct point or spur. Intercoxal tubercle lacking. Chelicera large; hand with usual 4 setae (*is*, *sb*, *b* and *es*) plus a variable number of accessory setae; galea rudimentary, especially in male, though silk ducts present. Carapace distinctly narrowed posteriorly; anterior margin with small, dentate epistome; with 20–24 (rarely 25 or 26) setae, of which 6–10 are at anterior margin and 4 (rarely 3, 5, or 6) near posterior margin; epigean species with 2 pairs of eyes, usually corneate; cavernicolous species lacking eyes, or with 1 or 2 pairs.

Remarks: *Apochthonius* is most closely allied to *Kleptochthonius*; in fact, the two groups were for a long while considered to be subgenera of the original genus *Apochthonius* (Chamberlin, 1929b). The two have in common the following characters: 1) unique spinelike setae ("coxal spines") on coxa I; 2) no intercoxal tubercle; 3) distribution of trichobothria on chelal fingers; 4) small sensillum on movable chelal finger between trichobothria *st* and *sb*. Notable differences include: 1) marginal teeth of chelal fingers contiguous in *Apochthonius*, but widely spaced in *Kleptochthonius*; 2) carapace broad anteriorly and distinctly narrowed posteriorly in most *Apochthonius*, but usually nearly rectangular in *Kleptochthonius*; 3) species of *Apochthonius* usually smaller than those of *Kleptochthonius*.

Apochthonius moestus (Banks)

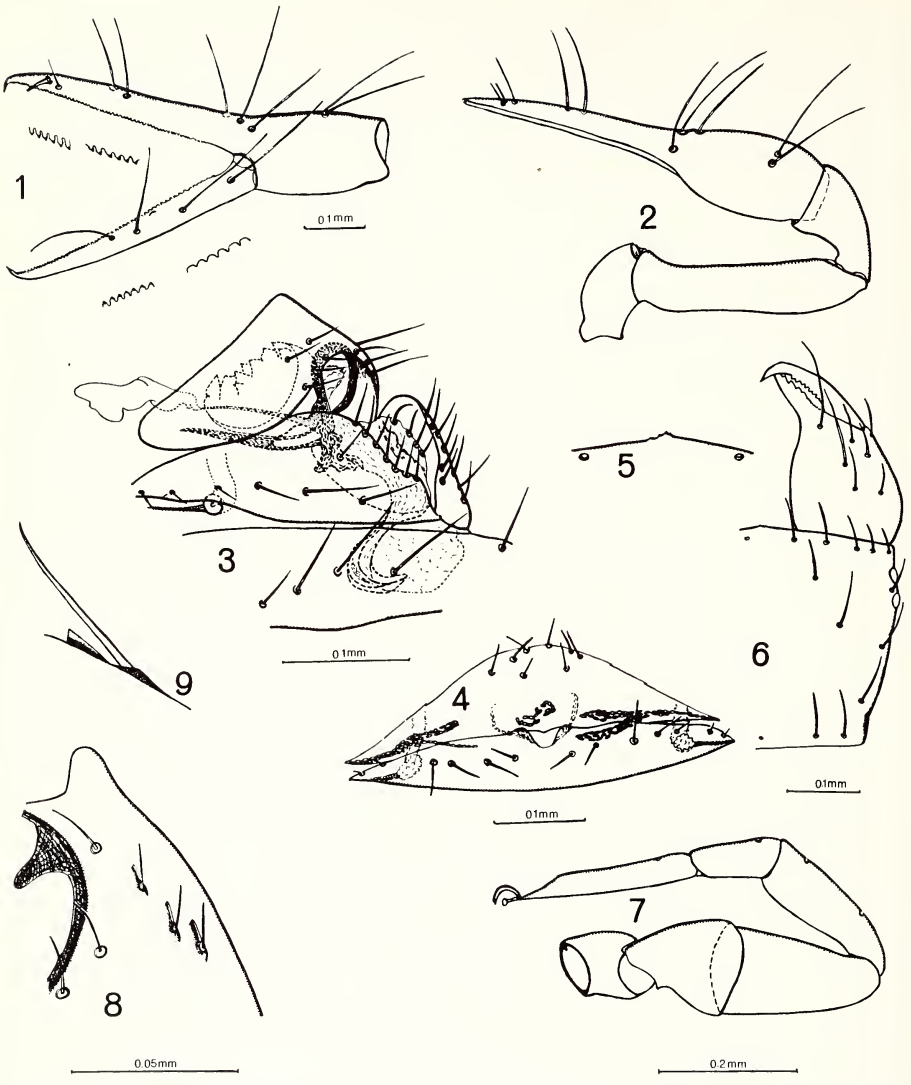
Figs. 1–9.

Chthonius moestus Banks, 1891, p. 165; 1895, p. 13.

Apochthonius moestus (Banks): Chamberlin 1929a, p. 67 (part): Beier, 1932, p. 41 (part): Hoff, 1958, p. 6 (part): Muchmore, 1963, p. 11; 1966, p. 278; 1967, pp. 89–92 (part): Benedict and Malcolm, 1973, pp. 695–696 (part). *Not* Chamberlin, 1929b, p. 153: *not* Hoff, 1944, p. 125; 1945, p. 311; 1946, p. 105; 1949, p. 434; 1951, p. 4; 1952, p. 42; 1956, p. 2; 1959, p. 4; *not* Hoff and Bolsterli, 1956, p. 158: *not* Schuster, 1966, p. 183.

Material upon which the redescription is based: Holotype female, collected by N. Banks sometime prior to 1891 from Ithaca, Tompkins County, New York, "under stones in spring" (Banks, 1891, p. 154); the specimen was mounted in Canada Balsam by J. C. Chamberlin and is deposited in the Museum of Comparative Zoology, Harvard University. One female (JC. 71.01001) from Enfield Glen, Tompkins County, New York, 20 October 1920, by C. R. Crosby. One male (JC. 70.01001) from "Deneyter County," New York, on 4 July 1922, by C. R. Crosby. [This locality listing is erroneous. The label reads, "Deneyter Lake, Madison County, New York," which also contains an error. The place is actually DeRuyter Lake, in the southwest corner of Madison County, about 40 miles NE of Ithaca.] Five males and 8 females (WM 851) on 28 November 1965, and 1 male and 2 females (WM 852) on 18 December 1965 from Taughannock Falls State Park, about 9 miles NW of Ithaca, Tompkins County, New York (W. B. Muchmore). Two males and 2 females (WM 1233) from Enfield Glen (R. H. Treman State Park), about 5 miles SE of Ithaca, New York, on 15 October 1967 (W. B. Muchmore). Nine males (WM 1633) from Ringwood Forest, about 7 miles E of Ithaca, New York, on 8 June 1968 (S. B. Peck).

Diagnosis (revised): With the characters of the genus as outlined above. Moderately small species (male 1.20–1.40 mm, female 1.25–1.45 mm body length); carapace normally with 24 vestitural setae of which 10 are at anterior margin and four near posterior margin; with 4 corneate eyes; movable chelal finger with occasional teeth slightly larger than the others.



FIGS. 1–9. *Apochthonius moestus* (Banks). 1. Lateral view of left chela; details of teeth 14–19 and 53–57 of fixed finger and of teeth 28–34 and 46–51 of movable finger. 2. Dorsal view of right palp. 3. Sublateral aspect of genital area of male (drawn by the late J. C. Chamberlin). 4. Genital area of female. 5. Epistomal area of carapace. 6. Carapace and right chelicera. 7. Leg IV. 8. Anterior half of right coxa I. 9. Lateral view of single "coxal spine."

Description of female (including holotype): With the general features of the genus. All parts pale tan. Carapace (Fig. 6) about as long as broad, markedly narrowed posteriorly; anterior margin with small, denticulate epistome in center and a few fine denticles laterally (Fig. 5); two pairs of moderate-sized, corneate eyes, posterior ones slightly smaller than anterior ones; anterior eyes about one ocular diameter from anterior margin of carapace, posterior eyes about one-half diameter from anterior ones; surface of carapace smooth dorsally, becoming distinctly reticulate laterally; chaetotaxy usually 10-4-4-2-4 = 24, but sometimes slightly different (rarely 9 or 11 at anterior margin, and 3, 5, or 6 at posterior margin); all setae of carapace shorter than width of palpal femur. Abdominal tergites and sternites entire; surfaces finely reticulate; pleural membranes covered with minute spinules; tergal chaetotaxy about 4:4:6:7:8:9:9:9:9:7:1T2T1:0; sternal chaetotaxy about 8:(4)6(4):(4)6(4):12:12:12:12:13:T2T2T2T:0:2; genital opercula as shown in Fig. 4. Coxal area unique; surfaces smooth; chaetotaxy usually 2-2-1:3-0-CS:2-2:2-3:2-3. Coxa I (Fig. 8) with pronounced, rounded apical process devoid of setae; with 3 characteristic setae ("coxal spines") on face, each seta long and acute, originating from socket in posterior half of a low, elongate ridge, the anterior end of which is produced into a distinct point or spur (Fig. 9). Intercoxal tubercle lacking.

Chelicera (Fig. 6) robust, about 0.85 as long as carapace; surface smooth except for patches of small, pointed, scalelike tubercles on hand dorsally and ventrally at bases of fingers; hand with 7 setae (*is*, *es*, *sb*, *b*, plus three accessory setae, in the notation of Chamberlin, 1931, pp. 64–65 and Fig. 13A); flagellum of 8 pinnate setae; movable finger with row of 9–12 teeth, becoming smaller basally and merging into a series of tiny granules; movable finger with an isolated tooth near tip and a row of 6–9 teeth diminishing in size basally; serrula exterior of about 17 blades, serrula interior of 11 or 12 blades; galea vestigial, barely elevated above finger margin around openings of silk ducts.

Palp moderately slender; femur about as long as carapace and chela about 1.5–1.6 times as long. Proportions of segments as shown in Fig. 2; trochanter 1.7–1.9, femur 4.1–4.55, tibia 1.65–1.9, and chela 4.3–4.8 times as long as broad; chelal hand 1.5–1.6 times as long as deep; movable finger 1.81–1.91 times as long as hand. Chelal dentition and chaetotaxy as shown in Fig. 1; in general, both fingers with contiguous marginal teeth, evenly graded in size and shape from base to tip, though an occasional tooth may be slightly longer or wider than adjacent ones; fixed finger with about 55–60 teeth, all with cusps except basal 3–5; movable finger with about 47–55 teeth, only the distal 18–25 being cusped, the more basal ones becoming rounded and low; small, elevated sensillum on outer surface of movable finger near dental margin, about midway between levels of trichobothria *st* and *sb*.

Legs relatively slender; legs IV of holotype lost, legs IV of others (Fig. 7) with entire femur 2.25–2.5, tibia 3.5–3.75, metatarsus 2.0–2.3, and telotarsus 5.5–6.0 times as long as deep. Long tactile setae on tibia about 0.45, on metatarsus about 0.25, and on telotarsus about 0.26 length of segment from proximal end.

Male: Essentially like female, but smaller and a little more slender. Genital opercula as shown in Fig. 3. Movable cheliceral finger usually without any evidence of an elevated galea, although silk ducts are present. Proportions of palpal segments: trochanter 1.65–1.95, femur 4.15–4.65, tibia 1.75–1.95, and chela 4.65–5.05 times as long as broad; chelal hand 1.6–1.75 times as long as deep; movable finger 1.89–2.00 as long as hand. Fixed chelal finger with 55–65 and movable finger with 50–60 marginal teeth; sensillum present on movable finger as in female.

Nymphs: Like the adults but paler, smaller, more robust, and with the reduced chaetotaxies characteristic of other chthoniids.

Measurements (mm): *Female* (First figures are for holotype, followed in parentheses by ranges for 14 other mounted females from Tompkins County, New York): Body length 1.42(1.25–1.45). Carapace length 0.415(0.42–0.48). Chelicera 0.385(0.36–0.41) by 0.19(0.185–0.215). Palpal trochanter 0.19(0.165–0.215) by 0.10(0.95–0.12); femur 0.415 (0.41–0.495) by 0.10(0.10–0.11); tibia 0.22(0.21–0.235) by 0.125(0.11–0.14); chela 0.67 (0.65–0.755) by 0.155(0.14–0.17); hand 0.245(0.225–0.27) by 0.155(0.14–0.18); movable finger 0.45(0.43–0.51) long. Leg IV: entire femur 0.385–0.45 by 0.16–0.185; tibia 0.265–0.30 by 0.075–0.08; metatarsus 0.13–0.15 by 0.06–0.065; telotarsus 0.245–0.27 by 0.045.

Male (Ranges for 9 mounted males from Tompkins County, New York): Body length 1.24–1.44. Carapace length 0.385–0.45. Chelicera 0.31–0.36 by 0.16–0.19. Palpal trochanter 0.16–0.19 by 0.095–0.11; femur 0.395–0.465 by 0.095–0.11; tibia 0.20–0.23 by 0.11–0.125; chela 0.64–0.72 by 0.13–0.155; hand 0.21–0.245 by 0.13–0.155; movable finger 0.41–0.48. Leg IV: entire femur 0.38–0.43 by 0.155–0.18; tibia 0.26–0.295 by 0.075–0.08; metatarsus 0.125–0.15 by 0.06–0.065; telotarsus 0.235–0.26 by 0.04–0.045.

Additional records of specimens apparently belonging to *A. moestus*: NEW YORK: Genesee County, Batavia and Bergen Swamp; Monroe County, Mendon Ponds Park and Powder Mills Park; Onondaga County, Tully Forest; Steuben County, Stony Brook Park; Tompkins County, along NY 89 5 miles N of Ithaca; Wayne County, Zurich Bog. PENNSYLVANIA: Tioga County, along Arnot Road S of Blossburg; Wayne County, 2 miles W of Hancock, NY; Berks County, Hawk Mountain; Schuykill County, Keefer Summit, near Reinerton; Clarion County, Cook Forest State Park; Carbon County, Palmerton and Little Gap; Northampton County, Fox Gap.

Specimens of *Apochthonius* not pertaining to *A. moestus* as defined have been found in numerous collections from central Pennsylvania (particularly the Susquehanna River Valley) southward and westward. Thus the distribution of this species appears to be limited to New York State and the northern and eastern parts of Pennsylvania.

Habitat: Banks found his specimens "under stones in spring" (1891, p. 165). The specimens taken by Muchmore and by Peck were obtained through Tullgren separation of damp litter from under and alongside logs or rotted stumps in mixed hardwood-conifer woodlands, mainly on hillsides along streams.

Remarks: As far as is known at present, *Apochthonius moestus* (Banks) is the only eastern member of the genus with 10 setae at the anterior margin of the carapace, and a total of 24 carapacial setae; all other forms have 8 or fewer setae at the anterior margin with a total of 22 or fewer. There are other differences as well, in the uniformity of chelal teeth, the position of the sensillum on the movable chelal finger, and size and proportions of various parts; but the details of these have yet to be worked out. *A. minimus* Schuster, and *A. malheuri* Benedict and Malcolm also have 10 setae on the anterior margin of the carapace with a total of 24. *A. moestus* can be distinguished from *A. minimus* by its larger size and the occurrence of only a small spur on the base of each coxal spine (see Benedict and Malcolm, 1973, pp. 625–626). *A. malheuri* is a large, troglobitic form with only two tiny eyes, impossible to confuse with *A. moestus*.

It is interesting to note that our specimens of *A. moestus* usually show some slight irregularity in the size of marginal teeth on the movable chelal fingers.

Occasional larger teeth were found by Hoff (1956) in *A. magnanimus* from New Mexico and were held to be an important difference between that species and *A. moestus*. Schuster (1966) has reported similar enlarged teeth on the chelal fingers of the 3 new species he described from the west coast. From our own observations it can be concluded that many specimens of *Apochthonius* from all over the United States have, on the movable finger, at least a few teeth which are larger than adjacent ones; therefore, it appears that this feature will have little taxonomic value until some patterns or degrees of difference have been detected.

The sensillum on the movable chelal finger appears to be a constant feature in all forms of *Apochthonius*. Its position seems to vary somewhat in different forms, but its usefulness as a taxonomic character is not yet clear. Similar sensilla have been observed in all other chthoniid pseudoscorpions we have examined (unpublished observations). The structure and position of these organs vary considerably among the genera and they may in future prove useful in establishing systematic relationships within the family.

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CONTENTS

Notes on hypopi (Acarina) associated with bees and wasps (Hymenoptera)[1]

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Abstract: Nine species of hypopial nymphs belonging to the families Acaridae, Chaetodactylidae, and Saproglyphidae are described as new: *Kuzinia* **affinis**, *K.* **americana**, *K.* **dispar** (Acaridae); *Vidia* **utahensis**, *Schulzea* **zahkvatkini** (Saproglyphidae); *Sennertia* **americana**, *S.* **ignota**, *S.* **indica** and *S.* **robusta** (Chaetodactylidae). A new subgenus, *Euvidia,* is established for 3 species in the genus *Vidia*; and *Vidia thomasi* is proposed as a new name for *Vidia cooremani* Baker in the Saproglyphidae. Hymenopterous hosts and figures of each species are given.

The hypopial stage or resting stage is a specific feature in the developmental cycle of the free-living Acaridae. It is formed between protonymph and tritonymph and is markedly different in structure from the nymphs or adults. The hypopus lacks functional mouthparts and has a suctorial plate on the venter of the body by which it attaches to the hosts. Obviously, in all mites which form hypopi, the hypopial stage assists in the dispersal of a species by attaching itself to the body of the host. Several species of mites belonging to the Acaridae, Chaetodactylidae and Saproglyphidae in the nymphal and adult stages are predators of wasps and bees. They kill the host eggs or larvae and then multiply and develop as scavengers on the food stored by their hosts (van Lith, 1957; Hirashima, 1957; Krombein, 1962a, b). However, in at least the Saproglyphidae, the symbiotic relationship between mites and wasps host is very complex (Krombein, 1961). The life cycle of the mite is successfully adjusted to that of the host, and the adult wasp host has an acarinarium on or in the body where the mites are arranged in layered rows (Krombein, 1961).

The discovery of new hypopial nymphs associated with different species of

Acknowledgments: We thank Dr. F. D. Parker, Bee Biology and Systematics Laboratory, USDA, ARS, Western Region, Logan, Utah for the bee mites from India which initiated this study. Other specimens were taken from bees in the New York State Museum and Science Service collection at Albany through the courtesy of Mr. J. Wilcox.

[1] Published by permission of the Director, New York State Science Service, Journal Series No. 181.

bees and wasps has prompted us to present this paper. Nine species belonging to the families Acaridae, Chaetodactylidae and Saproglyphidae are described as new. A new subgenus *Euvidia* is established, and a new name *Vidia thomasi* for *Vidia cooremani* Baker (preoccupied) is proposed in the Saproglyphidae.

Family Acaridae

Genus *Kuzinia* Zakhvatkin, 1941.

The genus *Kuzinia* was established for a single species: *Hypopus laevis* Dujardin, 1849. The male has anal copulatory suckers similar to those of *Aleuroglyphus* Zakhvatkin, and the larva has certain features found in the larvae of *Aleuroglyphus* and *Tyrolichus* Oudemans (see Zakhvatkin, 1941:127). The hypopus may be recognized by having large empodial claws on tarsi I–IV, small dorsal body setae and completely closed and widely separated coxal fields III. Coxal suckers are lacking; these are replaced by tiny setae. The gnathosoma is hidden ventrally, divided distally and may be segmented. The genus has not been previously reported outside the Palaearctic region; 3 new species are being described from North America. The hypopi were taken from different species of carpenter and bumble bees.

Kuzinia **affinis**, n. sp.

(Figures 1–7)

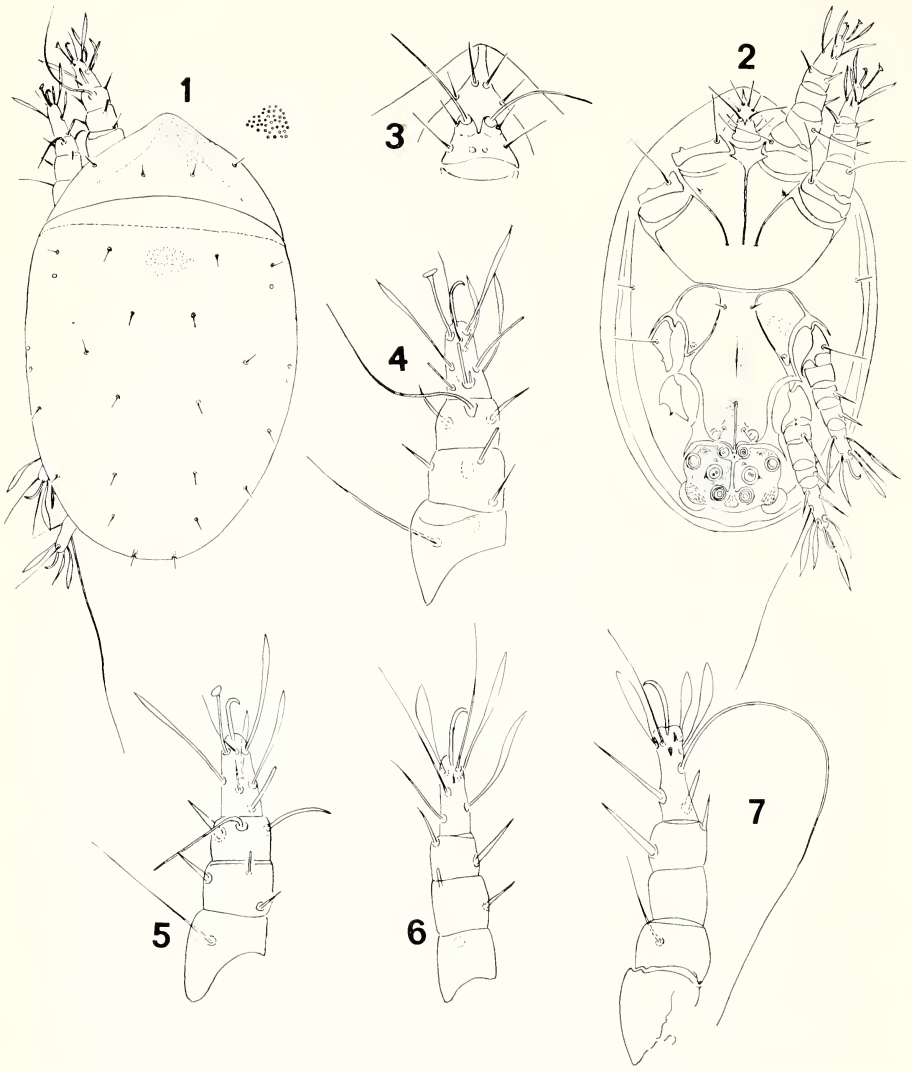
Hypopus. Idiosoma 281 μ long, 191 μ wide; elongate oval. Propodosoma and hysterosoma covered with minute punctations; all dorsal setae very small; chaetotaxy as figured, with d_2 widely separated from d_1, setae *Sai* removed from posterior edge of hysterosoma. Gnathosoma divided distally, unsegmented, with 2 long distal and 2 short lateral setae. Sternum thickened anteriorly at gnathosoma, the posterior end long, reaching as far as free ends of coxal apodemes II as figured. Coxal fields III closed, wide apart; genital field with free, longitudinal thickening at middle. Coxal suckers lacking, replaced by tiny setae. Suctorial plate wider than long, well sclerotized, with 3 pairs of suckers on the plate and 1 small pair on the open portion; a pair of suckers and setae located above the plate. Legs with large empodial claw on each tarsus. Tarsi I–II each with 1 long sucking seta and 4 narrow, lanceolate setae; tarsi III–IV each with 3 lanceolate setae. Tibia I with a strong and long dorsal seta. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 0; Genu–3, 3, 1, 0; Tibia–3, 3, 2, 2; Tarsus–7 (3), 7 (1), 6, 7.

Adults. Unknown.

Holotype. Hypopial nymph, Lakeville, New York, August 10, 1927, taken on *Bombus perplexus* Cresson by M. D. Delfinado. Deposited in New York State Museum & Science Service, Albany.

Paratypes. Twenty hypopial nymphs with same data as holotype; 14 hypopial nymphs, Kerner, New York, September 18, 1901, taken on *Psithyrus laboriosus* (Fab.) by M. D. Delfinado (on 2 sides mixed with *K.* **americana**, n. sp.); 10 hypopial nymphs, Speculator, Adirondack Mountains, New York, August 10, 1909, taken on bumble bee by M. D. Delfinado. Deposited in U.S. National Museum and New York State Museum & Science Service collections.

Remarks. The large size, shape of idiosoma and length of sternum will readily separate *K.* **affinis** from *K. laevis* (Duj.) and *K.* **americana** n. sp. *K. laevis* has 6 lanceolate



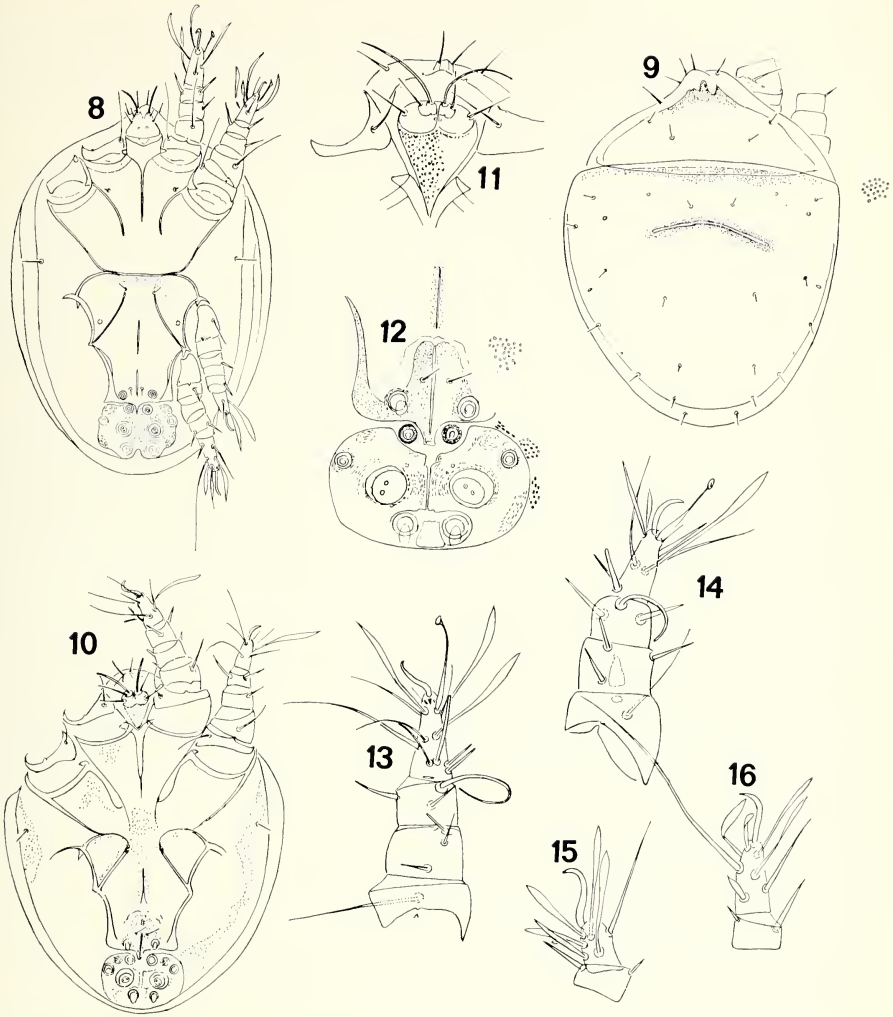
Kuzinia affinis, n. sp. 1, dorsal view; 2, ventral view; 3, details of gnathosoma; 4, leg I; 5, leg II; 6, leg III; 7, leg IV.

setae on tarsus III, 4 and IV, and 3 each on I–II; whereas **americana** and **affinis** both have 3 lanceolate setae on tarsi III–IV and 4 each on I–II.

Kuzinia **americana**, n. sp.

(Figure 8)

Hypopus. Idiosoma 223 μ long, 185 μ wide. Very similar to that of *K. affinis*, differing by the small size and broad hysterosoma, not narrowing posteriorly. Sternum short, not



Kuzinia americana, n. sp. 8, ventral view.

Kuzinia dispar, n. sp. 9, dorsal view; 10, ventral view; 11, details of gnathosoma; 12, details of suctorial plate; 13, leg I; 14, leg II; 15, tibia and tarsus III; 16, tibia and tarsus IV.

reaching free ends of coxal apodemes II. Seta *Sai* close to posterior edge of hysterosoma. Other characters are as in *K. affinis*.

Adults. Unknown.

Holotype. Hypopial nymphs, Kerner, New York, June 1928, taken on *Psithyrus laboriosus* (Fab.) by M. D. Delfinado. Deposited in New York State Museum & Science Service, Albany.

Paratypes. Twenty hypopial nymphs, Keene Valley, Essex Co., New York, August 5, 1889, taken on *Bombus vagans* Smith; 10 hypopial nymphs, Albany, New York, May 22, 1930, taken on bumble bee; 10 hypopial nymphs, "Lar. So. Colorado foot hills", no other data, taken on bumble bee, all were collected by M. D. Delfinado. Deposited in U.S. National Museum and New York State Museum & Science Service collections.

Kuzinia ***dispar,*** n. sp.

(Figures 9–16)

Hypopus. Idiosoma 274 μ long, 217 μ wide; broad oval. Propodosoma and hysterosoma minutely punctate; all dorsal setae very short; chaetotaxy that of a typical acarid as figured; seta d_2 displaced anteriorly and close to d_1; *Sai* near posterior edge of hysterosoma. Gnathosoma with shape and structure as figured, segmented and divided distally, bearing 2 pairs of distal setae and 1 pair basally. Sternum thickened, y-shaped with tip reaching as far as free ends of coxal apodemes II; coxal field II with faint indications of being closed, III closed and wide apart medially; coxal setae or suckers completely lacking. Genital field with free, longitudinal thickening at middle. Suctorial plate wider than long, well sclerotized, 3 pairs of suckers inside plate and 1 pair on open portion; 1 pair of suckers and setae just above the plate. Legs I–II robust; all legs with large empodial claws and well-developed stout setae. Tarsi I–II each with a peculiarly developed sucking seta—broadly lanceolate at basal half with a sucker at its terminal point, and 3 lanceolate setae; tarsi III–IV each with 4 lanceolate setae. Distal dorsal seta on tarsus IV not as long as that of other members of the genus. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 1; Genu–3, 3, 1, 0; Tibia–3, 3, 2, 2; Tarsus–12 (1), 9 (1), 7, 7.

Adults. Unknown.

Holotype. Hypopial nymph, U. S. National Museum type no. 3684, Kanda Ghat, Himachal Pradesh, (no date), taken from bumble bee (PL–480, Hissar, India), sent by F. D. Parker, USDA, Logan, Utah.

Paratypes. Two hypopial nymphs, with the same data as holotype. Deposited in U. S. National Museum collection.

Remarks. At present this new hypopus is being included in *Kuzinia* even though there are differences found on gnathosoma, type of leg setae and body chaetotaxy.

Family Saproglyphidae

Genus *Vidia* Oudemans, 1905.

Zakhvatkin (1941) divided the genus into 2 subgenera based on the type and number of flattened setae on tarsi I, II & III, structure of pretarsi I & II, and presence or absence of eyes. Nine species are included in the genus *Vidia,* and all but 1 species are known only from hypopial nymphs. A new subgenus *Euvidia* is established here for 3 species: *Vidia cooremani* Baker, 1964, *V. concellaria* Cooreman, 1948 and *V. utahensis,* n. sp., *Vidia cooremani* Baker, 1964 is preoccupied by *Vidia* (*Coleovidia*) *cooremani* Thomas, 1961 equals *Hemisarcoptes cooremani* (Thomas) in Hemisarcoptidae. We are therefore proposing *Vidia thomasi,* new name for *Vidia cooremani* Baker, 1964, not Thomas, 1961.

The 3 subgenera of *Vidia* may be separated as follows:

1. Tarsi I–II each with 3 lanceolate setae; pretarsi I–II small and normal in structure (on bees) ..... *Vidia* s. str.

2. Tarsi I–II each with 2 lanceolate setae; pretarsi I–II long, widened distally forming a spoon-shaped sucker (on *Crabro wasps*) ..... *Crabrovidia* Zakhvatkin.

3. Tarsi I–II each with only 1 lanceolate seta; pretarsi I–II large, bulbous (on sphecid wasps) ..... *Euvidia*, n. subg.

Subgenus *Euvidia,* n. subg.

Type-species, *Vidia* (*Euvidia*) **utahensis**, n. sp.

This new subgenus has the following features: eyes absent; tarsi I–II each with 1 lanceolate seta, III with 4 such setae; pretarsi I–II large and bulbous; pretarsus III small; tarsus IV without empodial claw but with very long, whiplike seta distally. Other characters as for the genus (see Zakhvatkin, 1941; Cooreman, 1948 a, b).

Vidia (*Euvidia*) **utahensis**, n. sp.

(Figures 17–23)

Hypopus. Idiosoma 217 μ long, 140 μ wide; ovoid. Dorsally with typical broken striate pattern and covered with minute punctations, transverse on prodosoma and longitudinal on hysterosoma; all dorsal setae very short with an acarid type arrangement: d_1 almost laterad of d_2, *hi* & *he* marginal, *Sai* & *Sae* dorsal, marginal, *pa* ventral. Gnathosoma lacking, represented by 2 long and 2 minute setae as figured. Sternum y-shaped, free; coxal field II closed posteriorly; coxal apodemes III & IV united medially forming an inverted v-shaped notch, with coxal setae located on each arm as figured. Apodeme of suctorial plate squarish; suctorial plate broad with well sclerotized posterior frame, 3 suckers inside plate and 2 outside. Legs as for genus, with III & IV very short; tarsi I–III each with a small empodial claw, lacking on IV but with a very long whiplike seta. Pretarsi I & II large, bulbous and appearing like suckers. Tarsi I & II each with 1 narrow lanceolate seta and 2 solenidia; tarsus III with 4 broad lanceolate setae; no such setae on tarsus IV. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 1; Genu–2, 2, 1, 0; Tibia–2 (1), 2 (1), 2, 1; Tarsus–5 (2), 5 (1), 5, 3.

Adults. Unknown.

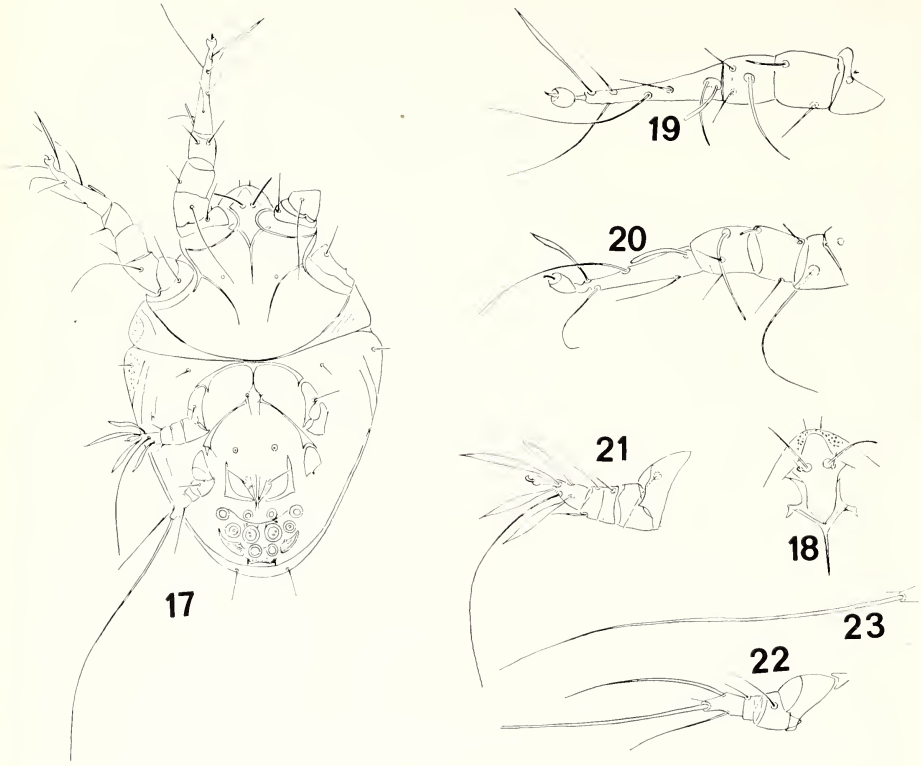
Holotype. Hypopial nymph, U. S. National Museum type no. 3685, Beaver, Utah, August 4, 1954, taken on a sphecid wasp, by Knowlton & Davis.

Paratypes. Fifteen hypopial nymphs with the same data as holotype. Deposited in U. S. National Museum and N. Y. State Museum & Science Service, Albany.

Remarks. The hypopus of this species is similar to that of *V. concellaria* Cooreman and *V. thomasi,* n. n. but differs by the structure of coxal apodemes III–IV, the shape of the suctorial apodeme, and the absence of the posterior sternum; also **utahensis** has fairly long coxal and genital setae.

Genus *Schulzea* Zakhvatkin, 1941.

The hypopus discussed here is probably not a true *Schulzea*; it possesses certain features of *Lackerbauria* Zakhvatkin as defined by Zakhvatkin (1941). [Baker (1962) described 2 species in *Lackerbauria*; we have reasons to believe that these species are not *Lackerbauria* but belong to an undescribed genus in Acaridae.] The segmented gnathosoma which is hidden beneath a sclerotized rostral protrusion, the very short dorsal setae, and widely separated, closed coxal fields II & III are characteristic of the type-species: *S. pamirensis* Zakhvatkin. As in *Lackerbauria,* empodial claws are present on tarsi I–IV,



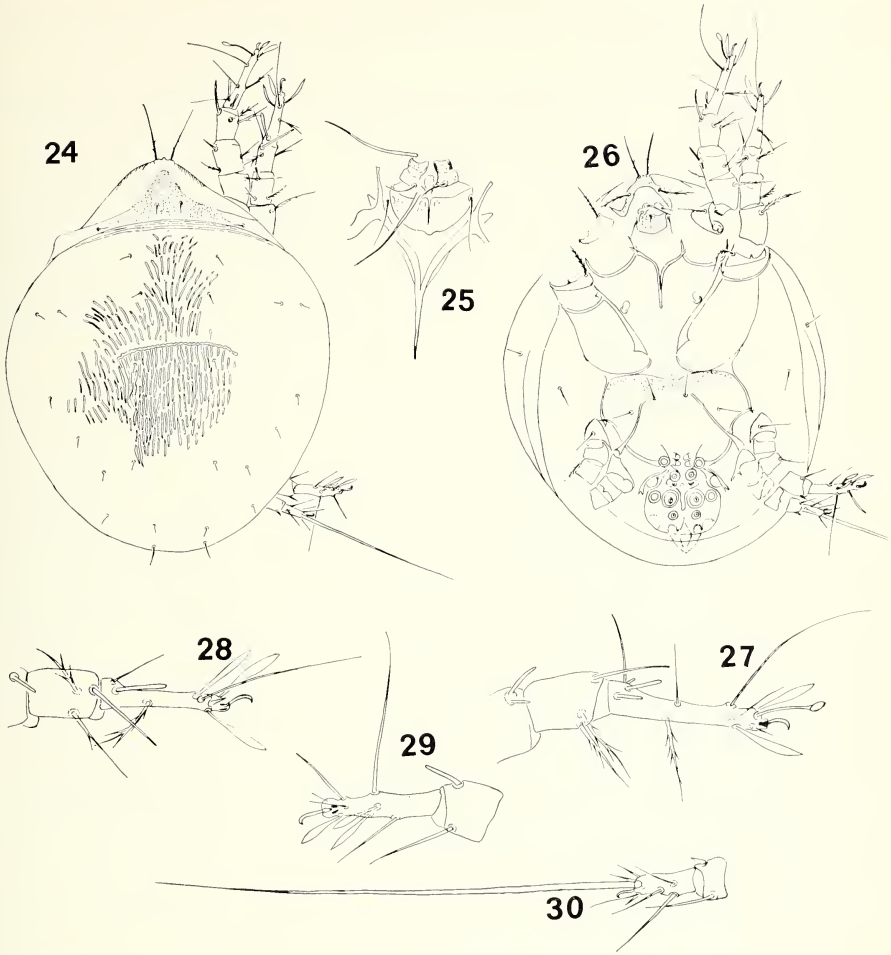
Vidia (*Euvidia*) *utahensis*, n. sp. 17, ventral view; 18, details of gnathosoma; 19, leg I; 20, leg II; 21, leg III; 22, leg IV; 24, distal segment of leg IV.

including a large, very long distal seta on tarsus IV. The genus *Schulzea* has been previously known only from Russia, where it is represented by 2 species. The hypopi of *Schulzea* are found associated with megachild and halictid bees, whereas those of *Lackerbauria* are found on wasps. Until we have seen specimens of typical *Lackerbauria,* it would be best to retain them in the present genus.

Schulzea **zakhvatkin**, n. sp.

(Figures 24–30)

Hypopus. Idiosoma 351 μ long, 287 μ wide; ovoid. Propodosoma small, produced anteriorly and with punctate arched sclerotization. Hysterosoma arched over propodosoma, densely punctate and with pattern of short, longitudinal striations as figured. All dorsal setae very short; chaetotaxy as figured. Gnathosoma small, segmented and hidden beneath a sclerotized rostral protrusion as figured; this structure bears 2 pairs of fairly long pectinate setae; distal segments of gnathosoma well separated, with 1 short seta on each segment. Sternum strongly y-shaped, free, short; coxal fields II & III closed, widely separated, with a pair of setae opposite coxal apodome III. Anterior coxal setae replaced by a pair of large suckers. Suctorial plate large, well sclerotized, open anteriorly; 3 pairs



Schulzea zakhvatkini, n. sp. 24, dorsal view; 25, details of gnathosoma; 26, ventral view; 27, tibia and tarsus I; 28, tibia and tarsus II; 29, tibia and tarsus III; 30, tibia and tarsus IV.

of suckers inside plate and 1 small pair on open portion; a pair of setae and suckers widely separated anterior to suctorial plate, and a pair of thickened discs between coxal apodemes and suctorial plate (as figured). Legs I & II with pectinate dorsal setae on all segments; empodial claws present on tarsi I–IV, and large, very long seta at end of tarsus IV. Tarsus I with 2 lanceolate and 1 sucking seta, II & III with 3 and 4 lanceolate setae respectively; no such setae on IV. Genu and tarsus of leg I each with duplex solenidia. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 1; Genu–2 (2), 2 (1), 2, 0; Tibia–3, 3, 2, 2; Tarsus–9 (3), 7 (1), 7, 8.

Adults. Unknown.

Holotype. Hypopial nymph, U. S. National Museum type no. 3686, taken on *"Halictus* sp. collected from Lucern" (no date) (PL–480, project Hissar, India), sent by F. D. Parker, Logan, Utah.

Paratype. One hypopial nymph, on same slide with holotype and with same data, in the U. S. National Museum.

Remarks. From Zakhvatkin's description and figure of *S. pamirensis* Zakhvatkin, *S.* **zakhvatkini** n. sp. appears related to *S. pamirensis. S. pamirensis,* however, has tarsus I shorter than genu and tibia I taken together and has 2 pairs of coxal suckers, and legs I & II lack pectinate and lanceolate setae. The structure of the suctorial plate is similar to that of *S. caucasus* Zakhvatkin but in **zakhvatkini** n. sp. tarsus I is as long as the genu and tibia I taken together, whereas they are longer in *caucasus.* Also, the gnathosoma of *caucasus* is not hidden ventrally.

Family Chaetodactylidae

Genus *Sennertia* Oudemans, 1905.

This genus contains 13 species, of which 11 are known only from hypopial nymphs; they are all associated with bees belonging to the subfamily Xylocopinae. The hypopi of *Sennertia* are characterized by having a hysterosomal shield, a striate pattern on the uncovered areas of the idiosoma, a very large twisted claw distally on tarsi I–III and a very long, whiplike seta on tarsus IV. The gnathosoma is lacking or reduced, represented by a pair of short setae. *S.* **americana** n. sp. is the first described member of this genus in North America.

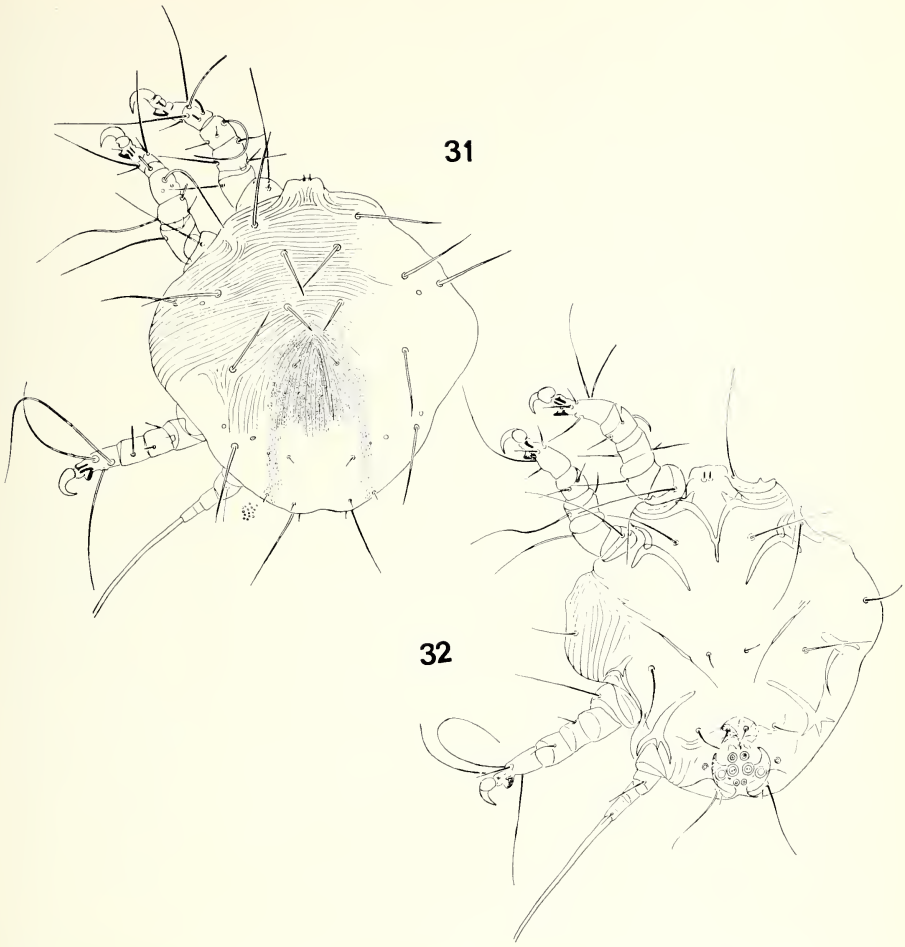
Sennertia **americana** n. sp.

(Figures 31, 32)

Hypopus. Idiosoma 319 μ long, 313 μ wide; almost quadrangular. Propodosoma with pattern of broken transverse striae, very long and strong dorsal setae *Sce* & *Sci.* Hysterosoma with a small, narrow shield, reaching anteriorly halfway to seta d_1 and with concentric striate pattern on uncovered areas; hysterosomal shield minutely punctate and well sclerotized (in recently molted specimens this shield is not sclerotized), with longitudinal pattern of broken striae, the posterior edge incised medially and folded on ventral surface of hysterosoma. Setae d_2, d_3 & d_4 very short, situated on hysterosomal shield; seta d_1 strong, as long as *Sci.* Setae *Sce, h_1, h_c, la* & *lp* very strong, long and almost subequal in length. Setae *Sai* & *pa* ventral in position. Gnathosoma lacking, only a pair of short, almost spinelike setae present. Sternum v-shaped, short. Apodemes II, III & IV free, reduced as figured. Coxal setae long and slender. Suctorial plate small, rounded, well sclerotized except anterior ⅓; 3 pairs of suckers inside the plate and 1 pair on the open portion; a small disc present on each side of the plate as figured. Legs as for genus, with very large twisted claw borne on each end of tarsi I–III; end of tarsus IV with a large, very long, whiplike seta. Tarsi I–III thickened distally, each with a thumblike lateral process. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 1; Genu–3, 3, 2, 0; Tibia–3, 3, 1, 0; Tarsus–5 (3), 4 (2), 4, 1 (terminal seta).

Adults. Unknown.

Holotype. Hypopial nymph, Albany, New York, June 6, 1901, taken on carpenter bee, *Xylocopa virginica* (L.) by M. D. Delfinado. Deposited in N. Y. State Museum & Science Service, Albany.



Sennertia americana, n. sp. 31, dorsal view; 32, ventral view.

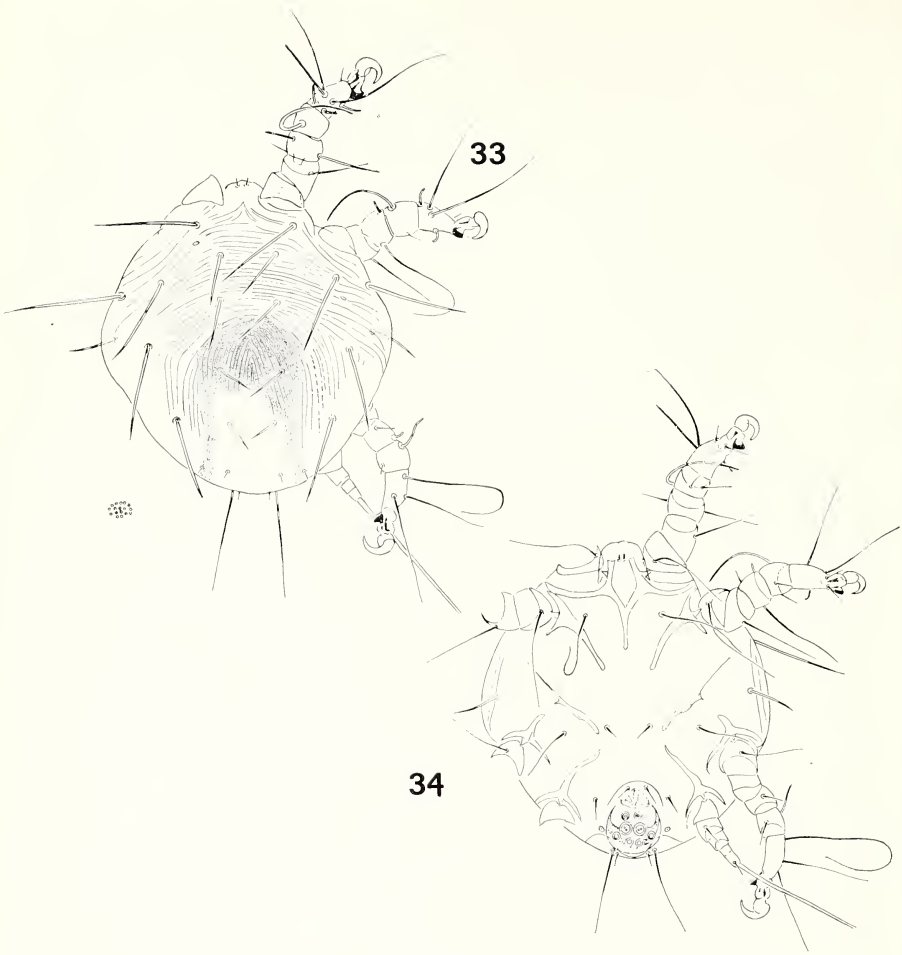
Paratypes. Forty-eight hypopial nymphs, Albany & Poughkeepsie, New York, June 6, 1901 and April, 1901, taken on carpenter bees by M. D. Delfinado; 11 hypopial nymphs, Lee County, Florida, Feb. 28, 1937, taken on *X. virginica* (no coll.). Deposited in U. S. National Museum and N. Y. State Museum & Science Service collections.

Remarks. The very short dorsal setae d_2, d_3, & d_4 on the hysterosomal shield is characteristic of *S.* **americana**; and like *S.* **ignota**, n. sp. and *S. alfkeni* Oudemans, it has a thumblike lateral process on tarsi I-III.

Sennertia **ignota**, n. sp.

(Figures 33, 34)

Hypopus. Idiosoma 300 μ long, 287 μ wide; almost rounded. Propodosoma and uncovered areas of hysterosoma with striae, the pattern on prodosoma broken transversely,



Sennertia ignota, n. sp. 33, dorsal view; 34, ventral view.

that on hysterosoma more or less concentric around hysterosomal shield. Dorsal setae *Sce*, h_1, h_c, *la* & *lp* very long and strong, subequal in length; *Sci* & d_1 subequal in length and shorter than above setae; d_2 & d_3 subequal and shorter than d_4 or *Sci*; d_4 very short to minute. Hysterosomal shield small and narrow, reaching as far forward as d_1, surface minutely punctate and with longitudinal broken striation pattern, the posterior edge deeply incised medially and folded on ventral surface of hysterosoma; setae d_2, d_3 & d_4 located on the shield. Setae *Sai* & *pa* ventral and situated on the folded hysterosomal shield. Gnathosoma lacking, a pair of minute setae present. Sternum y-shaped. Coxal apodemes II, III, IV free, reduced. Coxal setae very long, slender. Suctorial plate rounded, open at anterior half, with well-sclerotized frame, 3 pairs of suckers inside the plate and 1 pair on the open portion; one very small disc present on each side of the plate. Legs as for genus. Tarsi I–III each with a very large claw on each end, and thumblike

lateral process distally; end of tarsus IV with a very long seta. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 1, 1; Genu–3, 3, 2, 0; Tibia–3, 3, 2, 0; Tarsus–4 (3), 4 (1), 4, 1 (terminal seta).

Adults. Unknown.

Holotype. Hypopial nymph, Talara, Peru, May 6, 1934, taken on *Xylocopa* sp. by M. D. Delfinado. Deposited on N. Y. State Museum & Science Service, Albany.

Paratypes. Ten hypopial nymphs, with the same data as for the holotype. Deposited in U. S. National Museum and N. Y. State Museum & Science Service collections.

Remarks. This species is very similar to *S.* **americana** n. sp. differing by the shape of the idiosoma, the number of strong dorsal setae and the leg chaetotaxy. *S.* **americana** has d_2, d_3 & d_4 very short, whereas only d_4 is minute in *S.* **ignota**; all other dorsal setae are strongly developed.

Sonnertia **indica**, n. sp.

(Figures 35, 36)

Hypopus. Idiosoma 325 μ long, 255 μ wide; broadly oval and narrowing posteriorly. Propodosoma and uncovered areas of hysterosoma with striae, pattern on prodosoma more or less concentric, that on hysterosoma longitudinal laterally. Hysterosomal shield large, tongueshaped, minutely punctate and with longitudinal broken striate pattern as figured, the posterior edge slightly folded ventrally. Dorsal setae *Sce*, *hi*, *he*, *la* & *lp* long and strong. *Sci*, d_1, d_2, d_3 & D_4 very short to minute. Setae d_1–d_4 situated on hysterosomal shield. *Sai* & *pa* marginal. Gnathosoma lacking, represented by a pair of fairly long setae. Sternum v-shaped; coxal apodemes II–IV reduced, free; coxal setae fairly long, slender. Suctorial plate rounded, frame well sclerotized, 3 pairs of suckers inside the plate and 1 pair on the open portion. Legs as for genus. Tarsi III, III & IV not thickened distally and lacking lateral processes. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 1; Genu–3, 3, 2, 0; Tibia–3, 3, 1, 0; Tarsus–5 (3), 4 (1), 4, 1 (terminal seta).

Adults. Unknown.

Holotype. Hypopial nymph, U. S. National Museum type, no. 3687, India, 1.3.69, taken on *Tithitis binghami* (Cockerell) (PL–480, Hissar, India), sent by F. D. Parker, Logan, Utah.

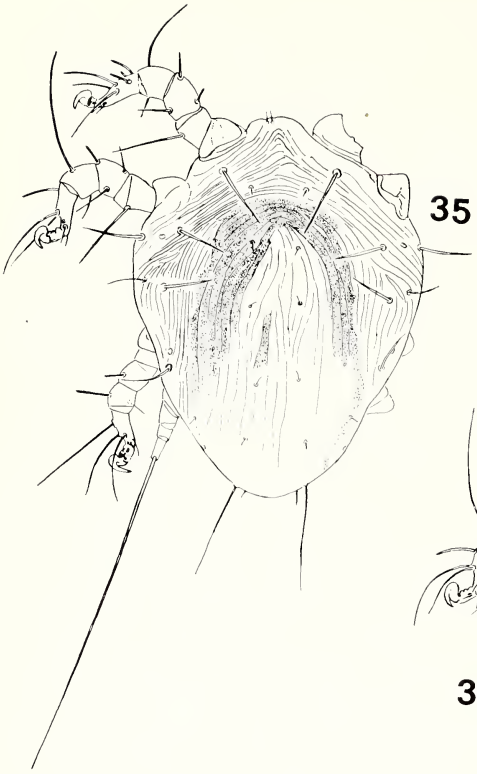
Paratypes. Two hypopial nymphs with the above data as holotype. Deposited in N. Y. State Museum & Science Service, Albany.

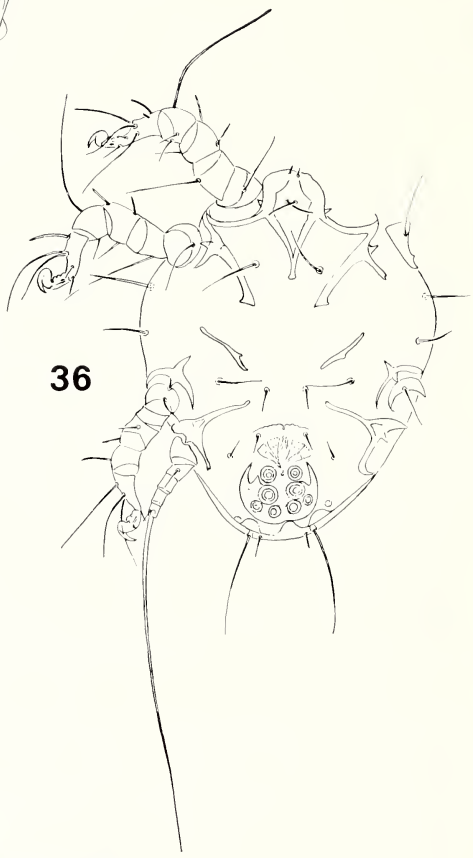
Remarks. The hypopus of *S.* **indica** may be distinguished from its closely related species *S.* **robusta**, n. sp. by the long and strong dorsal seta *lp*; this seta is minute in *S.* **robusta**.

Sennertia **robusta**, n. sp.

(Figures 37, 38)

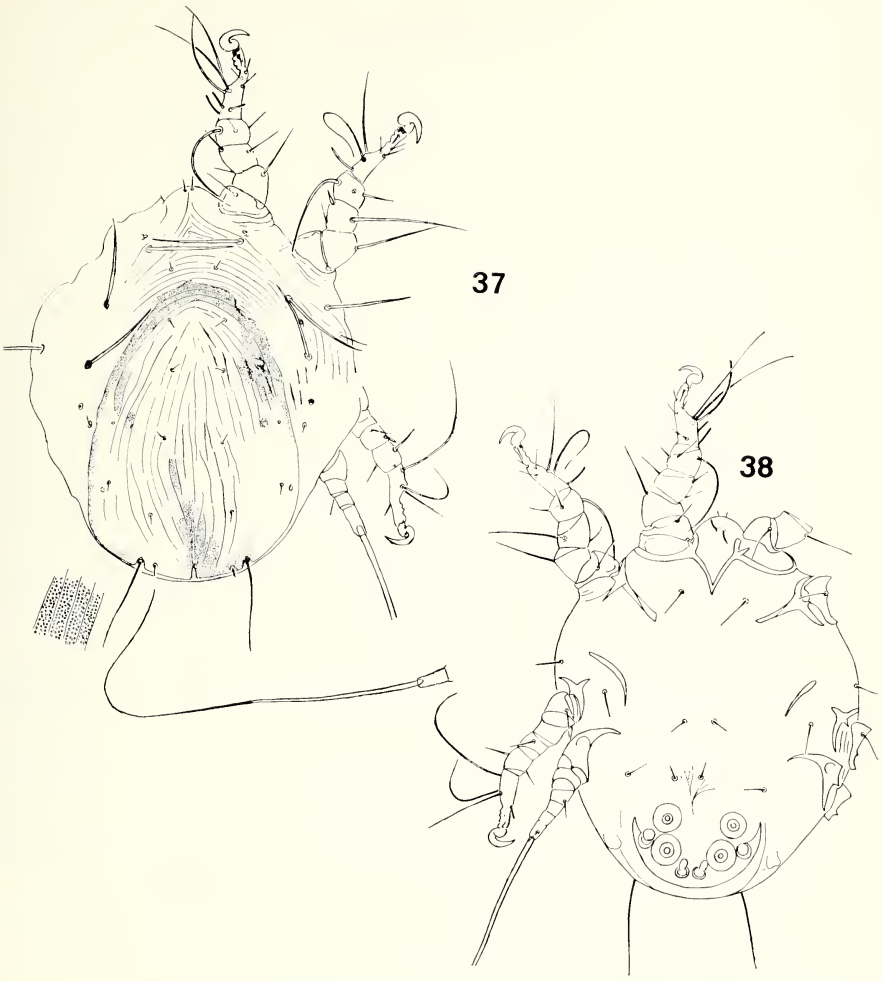
Hypopus. Idiosoma 355 μ long, 306 μ wide; broad oval. Propodosoma and uncovered areas of hysterosoma with more or less concentric striate pattern. Hysterosomal shield large, reaching anteriorly to seta *Sci*, minutely punctate and with strong longitudinal broken striate pattern as figured, the posterior edge not folded ventrally. Dorsal setae





Sennertia indica, n. sp. 35, dorsal view; 36, ventral view.

Sce, he, hi & *la* very strong and long; setae *Sci,* d_1, d_2, d_3, d_4 & *lp* minute; d_1–d_4 situated on hysterosomal plate; *Sai* & *pa* submarginal and dorsal in position. Gnathosoma lacking, only a pair of short setae present. Sternum v-shaped. Coxal apodemes II, III & IV free, reduced. Coxal setae fairly long, slender. Suctorial plate large with posterior ½–⅔ of the frame sclerotized; 3 pairs of suckers inside the plate and 1 large pair on the



Sennertia robusta, n. sp. 37, dorsal view; 38, ventral view.

open portion; 1 large disc present on each side of the plate. Legs as for genus. Tarsi I–III without distal lateral process. Chaetotaxy of legs I–IV: Trochanter–1, 1, 1, 0; Femur–1, 1, 0, 0; Genu–3, 3, 2, 1; Tibia–3, 3, 2, 0; Tarsus–5 (3), 5 (1), 4, 1 (terminal seta).

Adults. Unknown.

Holotype. Hypopial nymph, U. S. National Museum type no. 3688, India, 1.3.68, taken on megachilid bee (PL–480, Hissar, India), sent by F. D. Parker, Logan, Utah.

Paratypes. Two hypopial nymphs, "India," 1.3.69 & 26.2.69, taken from *Xylocopa* sp. (no other data). Deposited in the U. S. National Museum collection.

Remarks. This species is very similar to *S.* **indica,** n. sp. but the large size, leg chaetotaxy and minute dorsal seta *lp* will readily distinguish *S.* **robusta.**

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Phagism Relationships among Butterflies

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Abstract: Relationships of major families of Nearctic butterflies (Papilionidae, Pieridae, Lycaenidae, and Nymphalidae) to the taxa and growth-forms of their larval food-plants are investigated and compared to those of the Palearctic butterflies. The Palearctic butterfly fauna consists of more than three times as many species as the Nearctic fauna and yet the relative percentages of species in each of the families are strikingly similar. In terms of the butterflies in the four major families as a group, the greatest percentage of species in the Nearctic are monophagous with approximately equal percentages of oligophagous and polyphagous species; the greatest percentage in the Palearctic are oligophagous followed by a fairly high percentage of polyphagous species and a lower percentage of monophagous species. High percentages of herb- and of shrub-feeders and lower percentages of tree-feeders are found in both regions. A higher percentage of species are specialized (monophagous and oligophagous) than are generalized (polyphagous) on each plant growth-form (herbs, shrubs, and trees) in both regions, a seemingly unexpected finding based upon current theories of plant-herbivore interactions.

Although the distinctions between phagism categories are arbitrary, physiological differences exist in chemical perception and load of detoxication enzymes, but not in food utilization efficiencies, between herbivorous insects which are food-plant specialists and those which are food-plant generalists. Ecological advantages can be postulated for herbivorous insects with generalized and for those with specialized feeding habits (such as the ability to better survive in regions with unpredictable and/or physically harsh environments for the former and the potential to store toxic chemicals for protection for the latter) but it is clear that insects exhibiting all categories of phagism continue to exist in nature because of diverse selective pressures.

INTRODUCTION

Interactions between plants and animals are the subject of much current ecological and evolutionary research. One area of interest concerns the degree of specialization of animals feeding on plants. Several studies have mathematically formalized specialization patterns in food selection (e.g. Levins and MacArthur, 1969; Schoener, 1971), and broad patterns of food-plant specialization of animals characteristic of communities in different successional stages have been proposed (Feeny, 1975; Cates and Orians, 1975), but data de-

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scribing the patterns actually exhibited by animals have seldom been compiled and analyzed (e.g. Morse, 1971; Scriber, 1973; Cates and Orians, 1975). In this paper the relationships of the major families of Nearctic butterflies to the taxa and growth-forms of their larval food-plants are investigated and compared to those of the Palearctic butterflies (Kostrowicki, 1969). Furthermore, the data are examined in regard to the proposals of Feeny (1975) and Cates and Orians (1975) and a discussion of phagism categories is presented.

METHODS

An extensive survey of the literature was made to determine the genera of the larval food-plants of Nearctic butterflies. Although an attempt was made to exclude erroneous reports (Shields et al., 1969) it is likely that because of the magnitude of this project some errors in food-plant records are included. However, it is felt that these have not influenced to any appreciable extent the results presented. Growth-forms (i.e., tree, shrub, and herb) of the plants in these genera were determined, and the food-plant families were placed in orders following the treatment of Benson (1957). Lists of these data may be obtained from the author upon request. Data for Palearctic butterflies were recalculated from Kostrowicki (1969). The species of butterflies were classed as monophagous if the larvae feed on plants in only one genus and polyphagous if the larvae feed on plants in more than one order. Oligophagous species were defined as those with larvae feeding on plants in more than one genus but only in one order. The oligophagous category was further subdivided into species with larvae feeding on plants in one family and species with larvae feeding on plants in more than one family.

RESULTS AND DISCUSSION

Although the Palearctic butterfly fauna consists of more than three times as many species as the Nearctic fauna, the percentages of the total number of species that the species in each of the families make up are strikingly similar for both the Nearctic and Palearctic butterflies (Table 1). The greatest absolute difference occurs among the Satyridae which contains about 10% of the Nearctic and about 30% of the Palearctic species. Over 90% of all species of both Nearctic and Palearctic butterflies are contained in five families: the Papilionidae, Pieridae, Lycaenidae, Nymphalidae, and Satyridae (Table 1). Of these five main families, the Nearctic Satyridae contains the greatest percentage of species whose larval food-plant genera are not known. A reason for this is that many food-plant 'records' for satyrids merely list 'grasses' and/or 'sedges'. While probably all Nearctic satyrids are restricted to plants in one or both of these two families (Gramineae and Cyperaceae), distinct preferences of the satyrids for various plant genera may occur (Garth & Tilden, 1963) and because of this lack of food-plant records, the following

Table 1. Family composition of Nearctic and Palearctic (in parentheses) butterfly faunae and numbers and percentages of species with unknown larval food-plants.

Family	# Species	% Total	Species With Food-Plants Unknown #	%
Nymphalidae	140 (288)	32.4 (21.1)	52 (65)	37.1 (22.6)
Lycaenidae	133[1] (375)	30.8 (27.4)	44 (103)	33.1 (24.5)
Pieridae	58 (161)	13.4 (11.8)	15 (35)	25.9 (21.7)
Satyridae	47 (428)	10.9 (31.3)	22 (17)	46.8 (4.0)
Papilionidae	28 (93)	6.5 (6.8)	4 (33)	14.3 (35.5)
Riodinidae	19 (16)	4.4 (1.2)	9 (6)	47.4 (37.5)
Danaidae	5 (6)	1.2 (0.4)	3 (1)	60.0 (16.7)
Libytheidae	2 (1)	0.5 (0.1)	1 (0)	50.0 (0)
Totals	432 (1368)	100.1 (100.1)	150 (260)	34.7 (19.0)

[1] This value does not include *Feniseca tarquinius*, the larvae of which are carnivorous on aphids.

data and discussion deal only with the Papilionidae, Pieridae, Lycaenidae, and Nymphalidae.

That the families of butterflies have similarly diversified in relative numbers of species in both the Nearctic and Palearctic regions indicates similarities among the 'evolutionary success' of the families in the two regions. However, the similar relative diversification has resulted in close similarities among the percentages of polyphagous, oligophagous, and monophagous species only for the Pieridae of each region (Table 2). In terms of the butterflies of these four families as a group, the greatest percentage of species in the Nearctic are monophagous with approximately equal percentages of oligophagous and polyphagous species (Table 2). Shapiro (1973), although using somewhat different criteria[1], likewise found high percentages of monophagous and oligophagous species (about 30–50% in each category) and low percentages of polyphagous species (about 15–20%) in his study of the butterfly fauna of the different regions of New York state. The greatest percentage of species in the Palearctic are oligophagous, followed by a fairly high percentage of polyphagous species and a lower percentage of monophagous species (Table 2).

Various degrees of difference between families and regions occur in the association with plant growth-forms (Table 3). However, the similarities in total percentages for all four families are striking, with herb-feeders predominating in both regions (high percentages of shrub feeders also occur in both regions) (Table 3). If one assumes in a broad sense that the species diversity of herbivorous insects is positively influenced in part by the species

[1] Shapiro included all butterfly families (as well as the Hesperiidae) and he defined oligophagous species as those with larvae feeding on plants in two or more genera in the same family and polyphagous species as those with larvae feeding on plants in two or more families.

TABLE 2. Percentages of species of Nearctic and Palearctic (in parentheses) butterflies in four main families with known larval food-plants that are monophagous, oligophagous, or polyphagous.

Family	# Sp. known	% Known Sp. That Are: Monophagous (1 genus)	Oligophagous	Polyphagous (> 1 order)
Papilionidae	24 (60)	25.0 (25.0)	20.8 (70.0)	54.2 (5.0)
Pieridae	43 (126)	32.6 (30.2)	60.5 (63.5)	7.0 (6.4)
Lycaenidae	89 (272)	55.1 (21.7)	20.2 (44.9)	24.7 (33.5)
Nymphalidae	88 (223)	55.7 (18.4)	13.6 (23.3)	30.7 (58.3)
Totals	244 (681)	48.4 (22.5)	25.0 (43.5)	26.6 (34.1)

diversity of plants, then it would follow that the much greater species diversity of herbs over trees would result in a greater diversity of herb-feeders over tree-feeders. In support of this suggestion is the rather loose yet suggestive correlation between the number of butterfly species and the number of species of vascular plants in the various faunistic regions of the U.S.S.R. (Kostrowicki, 1969).

However, other factors are involved in the determination of insect diversity such that vegetational and herbivorous insect diversities do not necessarily correspond. Southwood (1960; 1961) has found that the number of insect species associated with trees is a function of the evolutionary history of the trees and of their abundance, while Strong (1974) maintains that this variation in insect species richness is explained solely by variations in host tree

TABLE 3. Percentages of species of Nearctic and Palearctic (in parentheses) butterflies in four main families with known larval food-plants that feed on trees, shrubs, and/or herbs.

Family	# Sp. Known	% Known Sp. That Feed On: Trees	Shrubs	Herbs	Total %
Papilionidae	24 (60)	54.2 (30.0)	83.3 (56.7)	54.2 (65.0)	191.7 (151.7)
Pieridae	43 (126)	37.2 (11.9)	44.2 (50.0)	74.4 (72.2)	155.8 (134.1)
Lycaenidae	89 (272)	49.4 (33.8)	70.0 (65.4)	60.0 (67.3)	179.4 (166.5)
Nymphalidae	88 (223)	23.9 (44.0)	51.1 (44.4)	77.3 (54.3)	152.3 (142.7)
Totals	244 (681)	38.5 (32.8)	59.8 (54.9)	68.0 (63.7)	166.3 (151.4)

Table 4. Number of species of vascular plants and herbivorous insects and the plant/insect species ratio for various locations in the northern hemisphere.

Place	# Species		Plants / Insect
	Vascular Plants	Herbivorous Insects	
New Jersey (40°N)	2,000[a]	5,200[b]	0.4
Connecticut (41°N)	2,500[c]	3,500[b]	0.7
Britain (50–60°N)[d]	1,600	6,000	0.3
Isachsen (78°N)[d]	50	1	50.0
Lake Hazen (82°N)[d]	100	40	2.5

[a] Britton (1889).
[b] Weiss (1924).
[c] Graves et al. (1910); Harger et al. (1930).
[d] Downes (1964).

ranges. Kostrowicki (1969) found no correlation between the number of species of trees, shrubs, and scrubs and the number of species of butterflies feeding on plants with these growth-forms in the various faunistic regions of the U.S.S.R. Among the New World swallowtail butterflies each 'group' associated with different major families of larval food-plants is most diverse (number of species) in the zones where the main larval food-plant families appear most diverse in terms of number of species, but the absolute numbers of swallowtail and plant species do not appear to be directly related (Slansky, 1972). For example, there are in the New World tropics approximately 60 species of swallowtails that feed on plants in the Aristolochiaceae of which there are some 80 species, while in the New World temperate zone there are only about a dozen species of swallowtails that feed on the Umbelliferae of which there are some 250 species. Another example of the lack of correspondence is the relatively greater decrease in insect species over plant species as one proceeds from the north temperate zone towards the Arctic (Table 4).

In as much as several butterflies are recorded as feeding on plants in more than one of the growth-form categories, the total percentages for each family in Table 3 and for each phagism category in Table 5 are greater than 100%. As discussed by Kostrowicki (1969) the degree to which the actual percentages deviate from 100% indicates in an inverse manner how 'attached' species in each of the butterfly families (Table 3) and in each of the phagism categories (Table 5) are to particular plant growth-forms. For example, among the Nearctic butterflies the Papilionidae has the largest total percentage value (Table 3) indicating that the species in this family are the least restricted to particular plant growth-forms.

In regard to the relationship of the phagism categories to growth-forms of the larval food-plants (Table 5), the total percentage values for polyphagous species in each family are greater than the values for monophagous species in each family in both regions (and may or may not be greater than the

TABLE 5. Percentage of the different phagism categories that feed on trees, shrubs, and/or herbs for species of Nearctic and Palearctic (in parentheses) butterflies in four main families with known larval food-plants.

Family	# Sp. Known	% Species That Feed On: Trees	Shrubs	Herbs	Total
		Monophagous			
Papilionidae	6	66.7	83.3	33.3	183.3
	(15)	(0.0)	(26.7)	(93.3)	(120.0)
Pieridae	14	64.3	78.6	35.7	178.6
	(38)	(29.0)	(84.2)	(26.3)	(139.5)
Lycaenidae	49	44.9	57.1	53.1	155.1
	(59)	(50.9)	(59.3)	(33.9)	(144.1)
Nymphalidae	49	12.2	34.7	79.6	126.5
	(41)	(51.2)	(53.7)	(24.4)	(129.3)
Totals	118	34.8	51.7	61.0	147.5
	(153)	(40.5)	(60.8)	(35.3)	(136.6)
		Oligophagous			
Papilionidae	5	40.0	40.0	80.0	160.0
	(42)	(35.7)	(64.3)	(57.1)	(157.1)
Pieridae	26	23.1	26.9	92.3	142.3
	(80)	(2.5)	(36.3)	(93.8)	(132.6)
Lycaenidae	18	33.3	77.8	77.8	188.9
	(122)	(19.8)	(70.5)	(85.2)	(175.5)
Nymphalidae	12	33.3	66.7	100.0	200.0
	(52)	(51.9)	(57.7)	(52.0)	(161.6)
Totals	61	29.5	52.5	88.5	170.5
	(296)	(23.0)	(58.1)	(77.4)	(158.5)
		Polyphagous			
Papilionidae	13	53.9	100.0	53.9	202.8
	(3)	(100.0)	(100.0)	(33.3)	(233.3)
Pieridae	3	33.3	33.3	100.0	166.6
	(8)	(25.0)	(25.0)	(75.0)	(125.0)
Lycaenidae	22	72.7	90.9	59.1	222.7
	(91)	(41.8)	(62.6)	(64.8)	(169.2)
Nymphalidae	27	40.7	74.1	63.0	177.8
	(130)	(39.2)	(36.2)	(65.4)	(140.8)
Totals	65	53.9	83.1	61.5	198.5
	(232)	(40.5)	(47.0)	(65.1)	(152.6)

values for oligophagous species) with the exception of the Pieridae. Thus in the Papilionidae, Lycaenidae, and Nymphalidae, species that are taxonomically polyphagous exhibit a greater degree of overlap in their association with growth-forms of larval food-plants than species that are taxonomically monophagous.

Of considerable interest are the percentages of species that exhibit each type of phagism on plants of each growth-form (Table 6). Feeny (1975)

Table 6. Percentage of herb-, shrub-, and tree-feeders in the different phagism categories for species of Nearctic and Palearctic (in parentheses) butterflies in four main families with known larval food-plants.

Family	# Sp. Known	% Species That Are: Monophagous (1 genus)	Oligophagous	Polyphagous (> 1 order)
		Herb-Feeders		
Papilionidae	13 (39)	15.4 (35.9)	30.8 (61.5)	53.9 (2.6)
Pieridae	32 (91)	15.6 (11.0)	75.0 (82.4)	9.4 (6.6)
Lycaenidae	53 (183)	49.1 (10.9)	26.4 (56.8)	24.5 (32.2)
Nymphalidae	68 (121)	57.4 (8.3)	17.7 (21.5)	25.0 (70.3)
Totals	166 (434)	43.4 (12.4)	32.5 (52.8)	24.1 (34.8)
		Shrub-Feeders		
Papilionidae	20 (34)	25.0 (11.8)	10.0 (79.4)	65.0 (8.8)
Pieridae	19 (63)	57.9 (50.8)	36.8 (46.0)	5.3 (3.2)
Lycaenidae	62 (178)	45.2 (19.7)	22.6 (48.3)	32.3 (32.0)
Nymphalidae	45 (99)	37.8 (22.2)	17.8 (30.3)	44.4 (47.5)
Totals	146 (374)	41.8 (24.9)	21.2 (46.0)	37.0 (29.1)
		Tree-Feeders		
Papilionidae	13 (18)	30.8 (0.0)	15.4 (83.3)	53.9 (16.7)
Pieridae	16 (15)	56.3 (73.3)	37.5 (13.3)	6.3 (13.3)
Lycaenidae	44 (92)	50.0 (32.6)	13.6 (26.1)	36.4 (41.3)
Nymphalidae	21 (99)	28.6 (21.2)	19.1 (27.3)	52.4 (51.5)
Totals	94 (224)	43.6 (27.7)	19.2 (30.4)	37.2 (42.0)

has suggested that broad differences may exist in the food-plant relationships of phytophagous insects characteristic of early successional communities and of those characteristic of late successional and climax forest communities, based on the following lines of reasoning: Because of the complexity of many temperate zone early successional communities in terms of the number of plant families represented by species containing different secondary chemicals (e.g. mustard oil glucosides in the Cruciferae, essential oils in the Umbelliferae,

cardiac glycosides in the Asclepiadaceae, alkaloids in the Solanaceae, and cyanogenic glycosides and alkaloids in the Leguminosae), the insects feeding on the plants in these communities are apparently involved in a form of biochemical coevolution that will tend to restrict the number of different plant species used as food. In contrast, because of the lower vegetational diversity of many temperate zone forest communities and because of relatively poor nutritive characteristics (e.g. tough leaves and low water content) and the presence of relatively generalized secondary chemicals (e.g. tannins and resins) in many of the plants, the insects feeding on the plants in these communities are apparently less subject to the restricting form of biochemical coevolution characteristic of the successional herb communities.

Cates and Orians (1975) suggest that early successional plant species, which are apparently selected for rapid growth to escape in 'time' from herbivores and which apparently escape in 'space' as well, would tend to devote less of their energy budget to defense against herbivores than later successional and climax plant species. Consequently, Cates and Orians (1975) predict, contrary to Feeny (1975), that herbivores feeding on early successional plants will tend to be more generalized in their food utilization patterns than herbivores feeding on later successional plants.

If one examines the total percentage values for species in all four families combined (Table 6), one finds some support for the predictions of both Feeny (1975) and Cates and Orians (1975). The high percentages of monophagous and oligophagous herb-feeders in the Nearctic, the high percentage of oligophagous herb-feeders in the Palearctic, and the fairly high percentages of polyphagous tree-feeders in both the Nearctic and Palearctic regions are expected, based on Feeny's (1975) suggestions. The low percentage of monophagous and considerably higher percentage of polyphagous herb-feeders in the Palearctic, and the high percentage of monophagous tree-feeders in the Nearctic support the suggestions of Cates and Orians (1975).

In relation to the polyphagous species, the oligophagous species can be considered as 'specialists' together with the monophagous species. For example, in the Nearctic most of the oligophagous species feed on plants in only one family (Table 7); see also discussion below of the phagism categories. The overall percentages of species in the monophagous and oligophagous categories (Table 6) can thus be combined as 'specialists' and compared to the overall percentages of polyphagous 'generalists' (Table 6) in the light of the proposals being discussed. One now finds that in both the Nearctic and Palearctic regions, the highest percentage of species feeding on each plant growth form are specialized (herb-feeders: Nearctic specialists, 75.9%, and generalists, 24.1%; Palearctic specialists, 65.2%, and generalists, 34.8%. Shrub-feeders: Nearctic specialists, 63.0%, and generalists, 37.0%; Palearctic specialists, 70.9%, and generalists, 29.1%. Tree-feeders: Nearctic specialists,

Table 7. Percentage of Nearctic oligophagous species of butterflies in four main families with known larval food-plants that feed on plants in one family or on plants in more than one family in one order.

Family	# Sp. Known	Nearctic Oligophagous Sp.		
		Total %	1 Family	>1 Family
Papilionidae	24	20.8	12.5	8.3
Pieridae	43	60.5	53.5	7.0
Lycaenidae	89	20.2	14.6	5.6
Nymphalidae	88	13.6	11.4	2.3
Totals	244	25.0	20.1	4.9

62.8%, and generalists, 37.2%; Palearctic specialists, 58.1%, and generalists, 42.0%). This indicates that the specializations suggested by Feeny (1975) for herb-feeders and by Cates and Orians (1975) for shrub- and tree-feeders are both prevalent.

Finally, the number of species of shrub-feeders can be combined with the number of species of tree-feeders since shrubs and trees would be expected to exhibit similar herbivore protection strategies (Cates and Orians, 1975), and the calculated percentages of specialized and of generalized shrub- and tree-feeders can be compared to the percentages of specialized and of generalized herb-feeders. In the Nearctic the percentage of specialized herb-feeders (75.9%) is greater than that of specialized shrub- and tree-feeders (62.9%) (Feeny, 1975), while in the Palearctic the respective percentages are very similar (65.2% and 66.1%). Clearly, the situation is complex and only further study can reveal what generalizations, if any, are appropriate. Nonetheless, the fact that a greater percentage of species are specialized than are generalized on all plant growth-forms seems to indicate that specialization, at least among the butterflies studied here, may be more prevalent than expected.

MONOPHAGY, OLIGOPHAGY, AND POLYPHAGY

The distinctions between polyphagous, oligophagous, and monophagous species are of course arbitrary. In the present study, following the categorization of Kostrowicki (1969), monophagous species are defined as those species with larvae feeding on plant species in only one genus. Such species are assumed to be both nutritional and chemical 'specialists', in that the plant species of a genus probably exhibit very similar nutritional and chemical properties. Polyphagous species are here defined as feeding on plants belonging in more than one order. Such species are assumed to be both nutritional and chemical 'generalists' in that the plant species of different orders probably exhibit a great degree of difference in their nutritional and chemical properties. Intermediate between these two categories are the oligophagous species, here defined as feeding on plants in more than one genus but all in one order. The

subdivision of this category for Nearctic butterflies into species that feed on plants in only one family and species that feed on plants in more than one family but restricted to one order (Table 7) reveals that in all four families more species feed on plants in one family than on plants in the different families of an order (the absolute difference is the least for the papilionids where only five species are involved). Thus in relation to polyphagous 'generalists', oligophagous species may be considered as 'specialists' together with the monophagous species.

In spite of this categorization, a certain degree of ambiguity still exists (Painter, 1936). A polyphagous species as defined here may actually be monophagous in terms of the secondary chemistry of the food-plant. For example, larvae of the imported cabbage butterfly, *Pieris rapae*, feed on plants in two separate orders but only on plants containing mustard oil glucosides (Verschaffelt, 1911; Hovanitz et al., 1963). In this regard, Dethier (1947) has suggested that the categories of phagism be divided according to the number of different secondary chemicals used as attractants and/or feeding stimulants by the species. A monophagous species as defined here may actually be a potential oligophagous or polyphagous species. For example, larvae of the West Virginia white, *Pieris virginiensis,* are restricted solely to *Dentaria* plants in the field, reasons for this including habitat selection and synchronization to the phenology of the plants. In the laboratory, however, adults will oviposit and larvae will feed and grow normally on plants in several other genera (Shapiro, 1971; Slansky, 1974). The application of phagism categories in this paper is at the level of the species, but it is clear, for example, that an oligophagous species may or may not be oligophagous at the level of the population and the individual (Neck, 1973; see also Downey & Fuller, 1961; Morse, 1971).

Nonetheless, there are definite distinctions between food-plant 'generalists' and 'specialists'. Fifty years ago Brues (1924) suggested that polyphagous insects might differ from monophagous ones in terms of "more variable instincts," "less restricted powers of digestion," and/or presence of "host races." If 'instinct' is interpreted to mean 'chemical perception' (Brues, 1920), then Brues was correct on this reason. It is now clear that while both generalist and specialist insect species are stimulated to feed by a variety of nutrient compounds (e.g. sugars and amino acids), it is the specialists that usually require the presence of specific secondary chemicals of plants to feed, and it is the specialists that are generally more sensitive to feeding deterrents (Thorpe et al., 1947; Beck, 1956, 1960; Beck & Hanu, 1958; Thorsteinson, 1956, 1958; DeWilde, 1958; Dadd, 1960; David & Gardner, 1966a, 1966b; Moon, 1967; Hsiao & Fraenkel, 1968; Ishikawa et al., 1969; Ma, 1969; Rees, 1969; Dethier & Kuch, 1971; Van Emden, 1972).

Brues' prediction of different digestive abilities between monophagous and

polyphagous insects (Dethier, 1954) appears to fall within the general supposition that a generalist is less efficient in exploiting a particular resource than a specialist for that resource (Morse, 1971). On the basis of rather limited evidence this supposition appears to be incorrect, at least in regard to the physiological food utilization efficiencies of insects. For example, Waldbauer (1964) found that when larvae of the tobacco hornworm, *Protoparce sexta*, which is a specialist insect feeding in nature on plants in the Solanaceae, were maxillectomized so that they would feed on normally rejected plants, the assimilation and growth efficiencies of larvae on some of the plants not normally eaten were almost as high as those exhibited by larvae on the normal food-plants (relative growth rates were however lower), implying that the specialization in this insect has mainly a chemical stimulatory and/or repellant rather than a 'digestive function' basis. SooHoo & Fraenkel (1966) found practically no differences between the assimilation and growth efficiencies of larvae of the generalist southern armyworm, *Prodenia eridania*, and larvae of the specialist silkworm, *Bombyx mori*, when both were fed leaves of white mulberry, *Morus alba* (the usual food of *B. mori*). Likewise, Slansky (1974) found no gross differences in assimilation and growth efficiencies between larvae of the specialist *Pieris virginiensis* and the generalist *P. rapae* when raised on similar food-plants.

A reason for this lack of gross differences in the food-plant utilization efficiencies of generalist and specialist insects is that the nutritional quality of the food-plant is of prime importance in determining the values of the utilization efficiencies (Slansky, 1974; Scriber, 1975), regardless of whether the insect is a specialist or generalist. While there thus appears to be no gross differences in the digestive abilities of specialist and generalist insects, generalist insect species do apparently carry a greater 'load' of detoxication enzymes than most specialist species, apparently because their generalist food habit subjects them to a wider range of potential toxins (Krieger et al., 1971).

Finally, Brues' third prediction regarding the presence of regional and/or seasonal preferences (i.e., Brues' host races) appears fairly well documented for insects of all phagism categories (Brues, 1923, 1946; Buxton, 1923; Brower, 1958a; Downey & Fuller, 1961; Neck, 1973).

Certain advantages associated with generalized and with specialized feeding habits can be postulated (Morse, 1971). For example, a generalized species is less dependent upon the fate of any one plant species and thus would presumably be better able to survive in regions with unpredictable and/or physically harsh environments (Buxton, 1923; Dethier, 1954; Schoener and Janzen, 1968). This supposition is supported by the fact that for the Palearctic butterfly fauna the greatest share of species in arctic and boreal zones are polyphagous (Kostrowicki, 1969), and by the fact that for the

Papilionidae of the world there is a higher percentage of polyphagous species in the temperate zones than in the tropical and subtropical zones (Slansky, 1972; Scriber, 1973). However, the few herbivorous insects found at high altitudes on mountains are primarily monophagous (Mani, 1968). Polyphagy may also allow a species to have a wide geographical distribution (Brues, 1920; Dethier, 1954; Pipkin et al., 1966), although an insect monophagous on a wide-ranging plant can similarly 'benefit' (Brues, 1920). Advantages of specialization, especially upon a generally distasteful plant, include the potential of storing toxic chemicals for protective purposes (Reichstein et al., 1968) and reduction in competition from other herbivores (Reichstein et al., 1968; Rees, 1969), although the specialization need not result from competition for food (Hairston, 1973).

Whatever the advantages and disadvantages of each category of phagism, one cannot conclude that one category of phagism or another is the 'best'. Although specialization is more prevalent than generalization for the butterflies studied here, insects in all categories of phagism continue to exist in nature, and this is clearly the result of diverse selective pressures (Dethier, 1954; Brower, 1958b; Schoener and Janzen, 1968; Levins and MacArthur, 1969; Feeny, 1975).

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Terrestrial Mites of New York-III. The family Scutacaridae (Acarina)[1]

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Abstract: A taxonomic survey is presented of the family Scutacaridae of New York. 23 species and 2 subspecies are described and illustrated from the collections made at Long Island and eastern New York. Of these, 14 species of *Scutacarus* Gros, and 7 species and 1 subspecies of *Imparipes* Berlese are new to science, and 3 European species are new records. *Imparipes apicola* (Banks) is a new combination. The mites treated are mainly the free-living predaceous, or fungivorous species. 102 figures are presented.

This third report is part of a continuing survey of the terrestrial mites of New York. It contains descriptions and illustrations of 23 species and 2 subspecies of Scutacaridae from the collections made at Long Island and eastern New York. Of these, 14 species of *Scutacarus* Gros, and 7 species and 1 subspecies of *Imparipes* Berlese are new to science, and 3 European species—*Scutacarus* (*S.*) *acarorum* (Goez), *Imparipes degenerans italicus* Berlese and *I. obsoletus* Rack are new records.

Scutacarids are found in a wide variety of habitats—in commercial mushroom houses, compost, forest litter, soil, humus, manure, in small bird and mammal nests, in nest cells of bees and wasps, on insects as well as on other mites. An increasing number of species are being found associated with hymenopterous insects, especially bees (Batra, 1965; Mahunka, 1969; Baker & Delfinado, 1975; Eickwort, pers. corresp.). Although the associations are generally considered harmless to the insects (hosts), but beneficial to the mites, information on the true relationship (beyond phoresy, see Norton & Ide, 1974) between mites and insects is lacking.

The present paper deals mainly with the free-living predaceous, or fungivorous species; the next report in this series will include the phoretic scutacarids associated with hymenopterous insects.

Holotypes are deposited in the New York State Museum & Science Service

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collection at Albany and paratypes in the U.S. National Museum collection. We thank Mr. Roy Norton (State University of New York at Syracuse) for his taxonomic opinions and the gift of specimens; Dr. George Eickwort (Cornell University) for the loan of specimens taken from bees, and Dr. Herbert W. Levi (Museum of Comparative Zoology, Harvard) for the loan of the type of *Disparipes apicola* Banks.

Genus *Scutacarus* Gros

Scutacarus Gros, 1845, Bull. Soc. imp. Moscow 18(1): 414. Type-species, *Scutacarus femoris* Gros, 1845, by monotypy, = *Acarus acarorum* Goeze, 1780 (see Oudemans, 1937:816). Karafiat, 1959, Beitr. Syst. u. Ökol. Mitteleurop. Acarina 1(2): 655. Mahunka, 1965, Acta Zool. Acad. Sci. Hung. 11: 363

Disparipes Michael, 1884, J. Linn. Soc. Lond. 17: 390. Type-species, *Disparipes bombi* Michael, 1884, by monotypy.

The genus *Scutacarus* is distinguished in having 4-segmented leg IV, usually with short tibiotarsus bearing 7 setae (rarely 6) and without pretarsus, claws and empodium. Leg I is also 4-segmented, and may or may not have claws. There are always 4 solenidia of varying forms on tibiotarsus I.

The genus is worldwide in distribution and, at present, contains the majority of the described species of the family Scutacaridae. Mahunka (1965) presented a key to the world species. Eight species have previously been known from North America.

The 15 species presently described in this genus may be separated into 2 subgenera: subgenus *Variatipes* Paoli (without a claw on tibiotarsus I) and subgenus *Scutacarus* Gros (with a claw on tibiotarsus I).

Subgenus *Variatipes* Paoli

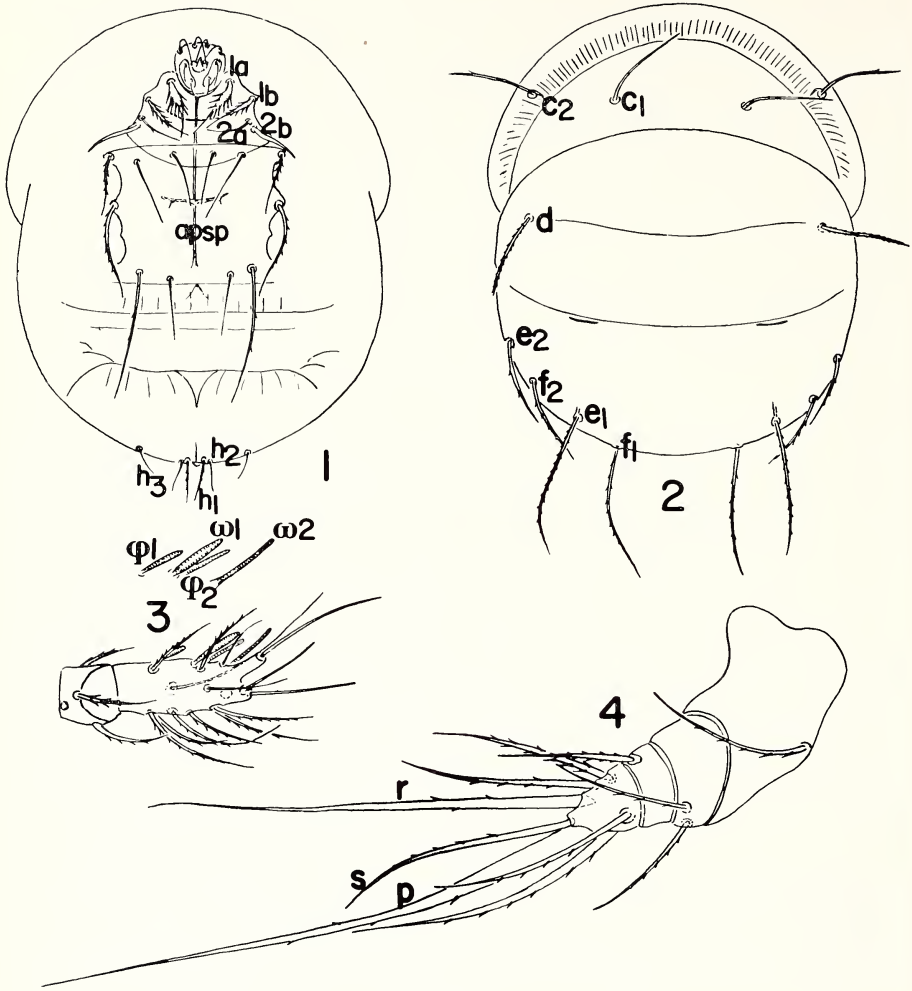
Variatipes Paoli, 1911, Redia 7(1): 222. Type-species, *Disparipes nudus* Berlese, 1886, by original designation.

Scutacarus, subgenus *Variatipes* Paoli, Karafiat, 1959, Beitr. Syst. u. Ökol. Mitteleurop. Acarina 1(2): 653.

The genus *Variatipes* was originally proposed by Paoli (1911) in the family Disparipedidae = Scutacaridae for species having "*Pedes primi paris unque destituti. Pedes postici ex quator articulis constituti, setis pluribus longis terminati.*" Karafiat (1959) recognized *Variatipes* as a subgenus of *Scutacarus* for species without a claw on tibiotarsus of leg I. We also consider these features as the diagnostic bases for the characterization of the subgenus *Variatipes*.

Scutacarus (*Variatipes*) **affinis**, n. sp.
(Figures 1–4)

Female (*Holotype*). Idiosoma 166 μ long, 134 μ wide, elliptical. Dorsum (fig. 2). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* not seen. Setae *c1* as long as



FIGS. 1–4. *Scutacarus* (*V.*) *affinis*, n. sp. 1. Female venter. 2. Female dorsum. 3. Genu, tibiotarsus and solenidia of leg I. 4. Leg IV.

c2, simple; *c2* barbed distally; *d* strong, barbed, as long as *e2* and *f2*, the latter sparsely barbed; *e1* and *f1* slender, barbed, longest of dorsal setae.

Venter (fig. 1). Posterior coxisternal plate more sclerotized and finely punctate than anterior coxisternal plate. Apodeme 2 well developed, attached to acetabula of leg II. Apodemes 1 and 3 and sternal apodeme (*apsa*) strong. Apodeme 4 not fully developed, weakly attached to acetabula of leg III; a small secondary apodeme visible below *ap4*. Sternal apodeme (*apsp*) with posterior end free. Epimeral setae *1a* large, strongly serrate; *1b* barbed at basal ½; *2a* slender, barbed at middle; *2b* slender, daggerlike, simple; *3a* as long as *3b*, slender, simple; *3c* barbed; *4a* as long as *4b*, simple; *4b* sparsely barbed, as strong as *4c* but longer; *4a* and *4b* arranged in a straight transverse row. Caudal setae

h2 and *h3* simple; *h1* sparsely barbed, stronger and longer than *h2* or *h3*; *h1* and *h2* approximate at their origins; *h3* distinct. Tibiotarsus of leg I as in figure 3. Solenidion ω_2 long and slender, rodlike; ω_1 club-shaped, shorter than ω_2; φ_2 similar to ω_2 but shorter; φ_1 swollen, shorter than φ_2. Tarsus II solenidion ω_1 same form and size as ω_1 of tibiotarsus I. Tibia II and III solenidion φ_1 small, club-shaped, and same size. Seta *d* of genu of leg I serrate. Leg IV as in figure 4. Tibiotarsus short, about as long as its basal width, with 7 sparsely barbed setae; seta *p* largest and longest of apical setae, bare at basal ½; *s* slender, short.

Male. Unknown.

Holotype. Female, Albany County Airport, New York, August 17, 1974, taken from litter in a wooded area near airport by M. D. Delfinado.

Paratype. 1 female, with same data as holotype.

Remarks. This species is similar to *quadrangularis* (Paoli) and **contiguus**, n. sp., in many respects. But **affinis**, n. sp. differs in having long dorsal setae *e1* and *f1*; strongly developed epimeral setae *1a* and *1b*, and slender solenidion φ_2 which is shorter than ω_2. Solenidion φ_2 is rodlike and very long, as long as ω_2 in *quadrangularis*; club-shaped and much shorter than in *contiguus*.

Scutacarus (*Variatipes*) **contiguus**, n. sp.
(Figures 5–8)

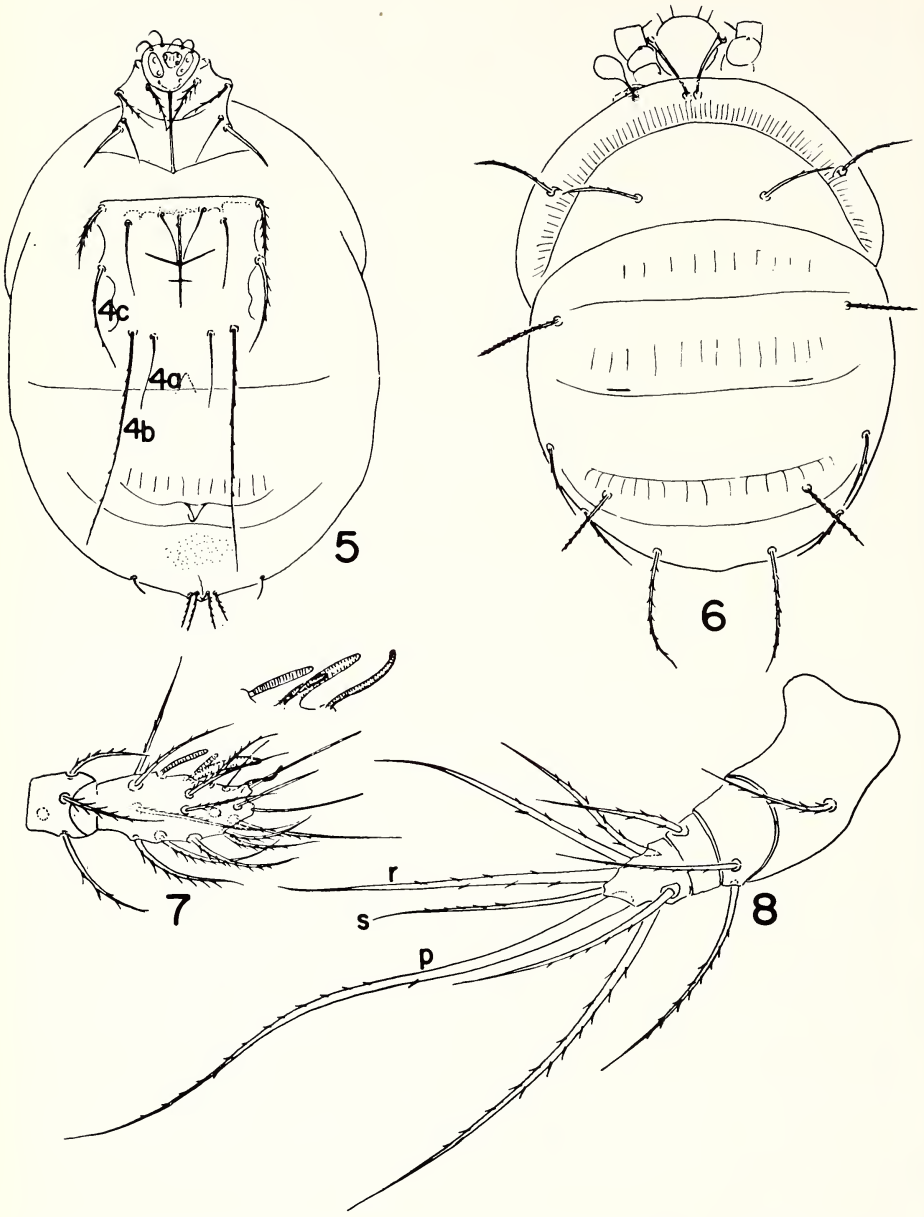
Female (*Holotype*). Idiosoma 191 μ long, 140 μ wide, narrow elliptical. *Dorsum* (fig. 6). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* not seen. Setae *c1* as long as *c2*, sparsely barbed; *d* as long as *e1*, moderately barbed; *e2* and *f2* sparsely barbed, fairly weak, shorter than *e1*; *f1* barbed, longest of dorsal setae.

Venter (fig. 5). Coxisternal plates well sclerotized and finely punctate. Apodeme 2 developed but weak, joining acetabula of leg II. Apodemes 1 and 2, and anterior apodeme (*apsa*) strong. Apodeme 4 incomplete, as short lateral extensions of sternal apodeme (*apsp*). Sternal apodeme (*apsp*) strong, with posterior end free. Epimeral setae *1a* similar to *1b*, slender, sparsely serrate; *2a* slender, simple, weak; *2b* daggerlike, simple; *3a* shorter than *3b*, simple; *3c* strong, serrate; *4a* short, about ⅓ as long as *4b*, simple; *4b* strong, sparsely serrate, long, almost reaching posterior margin of hysterosoma; *4c* sparsely serrate, ⅔ as long as *4b*; *4a* and *4b* arranged in a straight transverse row. Caudal setae *h1* and *h2* finely serrate, approximate at their origins; *h3* small, simple, shorter than *h1* and *h2*, distant. Tibiotarsus of leg I as in figure 7. Solenidion ω_2 very long and slender, recurved; ω_1 stout, about as long as ω_2; φ_1 and φ_2 club-shaped, short. Tarsus II solenidion ω_1 stout, similar to that on tibiotarsus I. Tibia II and III solenidion φ_1 small, club-shaped, that on tibia III much smaller. Leg IV as in figure 8. Tibiotarsus longer than its basal width, with 7 sparsely serrate setae; setae *s*, *r* and *p* as in **affinis**, n. sp.

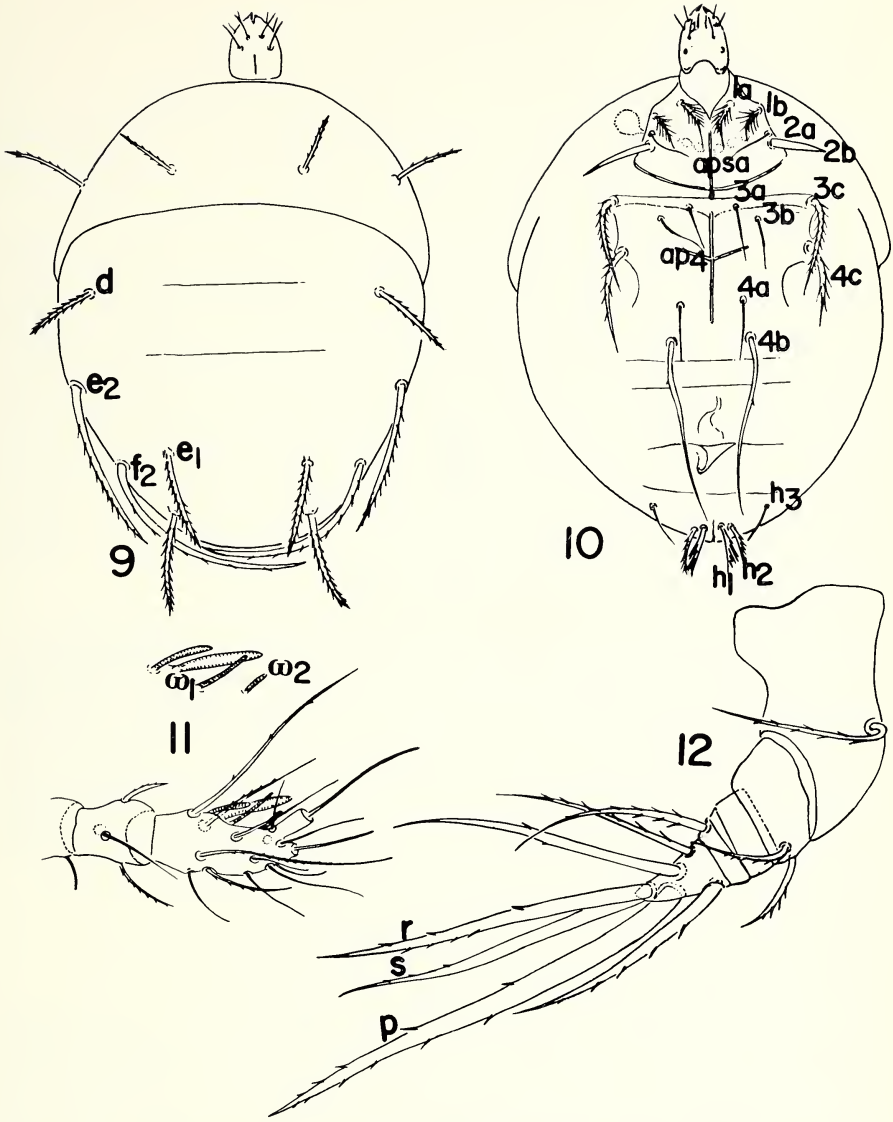
Male. Unknown.

Holotype. Female, Albany County Airport, New York, August 17, 1974, taken from litter in a wooded area on Shaker Road 1 mi west of airport by M. D. Delfinado.

Paratype. 1 female, with same data as holotype, but smaller—185 μ long, 128 μ wide; 1 female, Ellis Ringwood Preserve, New York, October 4, 1970 from center of decaying



FIGS. 5–8. *Scutacarus* (*V.*) *contiguus*, n. sp. 5. Female venter. 6. Female dorsum. 7. Genu, tibiotarsus and solenidia of leg I. 8. Leg IV.



Figs. 9–12. *Scutacarus* (*V.*) *jacoti*, n. sp. 9. Female dorsum. 10. Female venter. 11. Genu, tibiotarsus and solenidia of leg I. 12. Leg IV.

tree stump collected by G. R. Muller; 1 female, Ithaca, New York, May 8, 1974, from interior portion of nest of *Microtus pennsylvanicus* (Ord) collected by B. OConnor.

Remarks. The long, recurved solenidion ω_2 of tibiotarsus I and the long dorsal setae *f1* are distinctive for this new species.

Scutacarus (*Variatipes*) **jacoti**, n. sp.
(Figures 9–12)

Female (*Holotype*). Idiosoma 179 μ long, 140 μ wide, obovate.

Dorsum (fig. 9). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* not seen. All dorsal setae very strong; *c1* as long as *c2* and *d*, barbed; *e1* as long as *f1*, slightly longer than *d*, barbed; *e2* serrate, as strong as *f2* but shorter; *f2* strongest and longest of dorsal setae, serrate.

Venter (fig. 10). Coxisternal plates poorly sclerotized. Apodeme 2 not developed, hardly discernible. Apodeme 4 incomplete, seen as short lateral extensions of sternal apodeme (*apsp*). Apodemes 1 and 3, and sternal apodemes (*apsa*, *apsp*) very strong, the last with posterior end free. Epimeral setae *1a* and *1b* strongly pectinate; *2a* simple; *2b* robust, daggerlike, simple; *3a* as long as *3b*, simple, small; *3c*, *4c* strong, with strong serrations; *4a* simple, short, situated anterior to *4b*; *4b* very strong and long, reaching bases of caudal setae, smooth or barbed. Caudal setae *h1* large, plumose; *h2* similar to *h1* except smaller; *h3* simple, as long as *h1*, distant; *h1* and *h2* approximate at their origins. Tibiotarsus of leg I as in figure 11. Solenidion ω_2 very small; ω_1 large, club-shaped; φ_2 slender, rodlike, longer than φ_1; φ_1 club-shaped. Tarsus II solenidion ω_1 fairly stout. Tibia II and III solenidion φ_1 small, that on tibia III much smaller. Seta *d* of genu of leg I simple. Leg IV as in figure 12; tibiotarsus longer than its basal width, with 6 setae as shown in figure; setae *s*, *r* and *p* very strong and stout.

Male. Unknown.

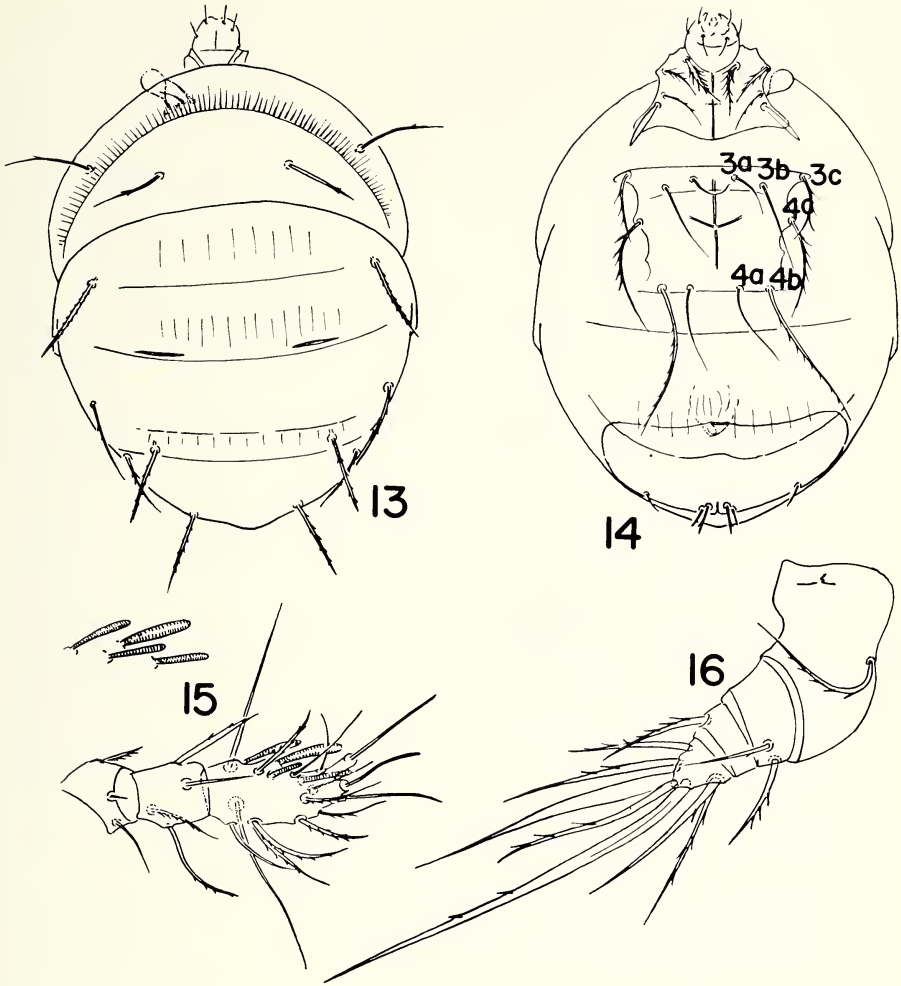
Holotype. Female (unique), boggy thickets 5 mi. east of Taborton, Rensselaer County, New York, August 5, 1974, taken from sphagnum moss by M. D. Delfinado. The moss was kindly given to us by Mr. S. J. Smith (Botanist, New York State Museum & Science Service at Albany).

Remarks. *S.* **jacoti** differs from other members of the subgenus *Variatipes* in several respects: epimeral setae *4b* are very strong, long and not in line with setae *4a*; solenidion ω_1 of tibiotarsus I is very small, and dorsal setae *f2* are well developed and long. An interesting feature of this species is the presence of 6 setae on the tibiotarsus of leg IV.

Scutacarus (*Variatipes*) **uniformis**, n. sp.
(Figures 13–16)

Female (*Holotype*). Idiosoma 179 μ long, 134 μ wide, obovate.

Dorsum (fig. 13). Sensillus capitate, smooth (?); prodorsal setae *pd1* and *pd2* minute, setiform. Setae *c1* as long as *c2* with 1–2 barbs at middle; *d* barbed, as long as *e1* and *f1* but stronger; *e2* and *f2* slender, sparsely barbed. *Venter* (fig. 14). Coxisternal plates poorly sclerotized. Apodeme 2 not developed, hardly discernible. Apodemes 1 and 3, and sternal apodemes (*apsa*, *apsp*) very strong. Apodeme 4 incomplete, with no trace of attachment to acetabula of leg III; a small secondary apodeme visible below *ap4*. Sternal apodeme (*apsp*) with posterior end free. Epimeral setae *1a* large, plumose; *1b* similar to *1a* except smaller; *2a* slender, barbed; *2b* daggerlike, smooth; *3a* and *3b* simple, the latter about ⅓ longer; *4a* simple, slender, about ⅔ as long as *4b*; *4c* barbed, as long as *4a* but stronger; *4b* very long but not reaching bases of caudal setae, barbed; *4a* and *4b* arranged in a straight transverse row. Caudal setae *h1* strong, barbed at middle; *h2* and *h3* simple, slender and shorter than *h1*; *h3* distant; *h1* and *h2* approximate at their origins. Tibiotarsus of leg I as in figure 15. Solenidion ω_2 rodlike, as long as ω_1; ω_1 stout,

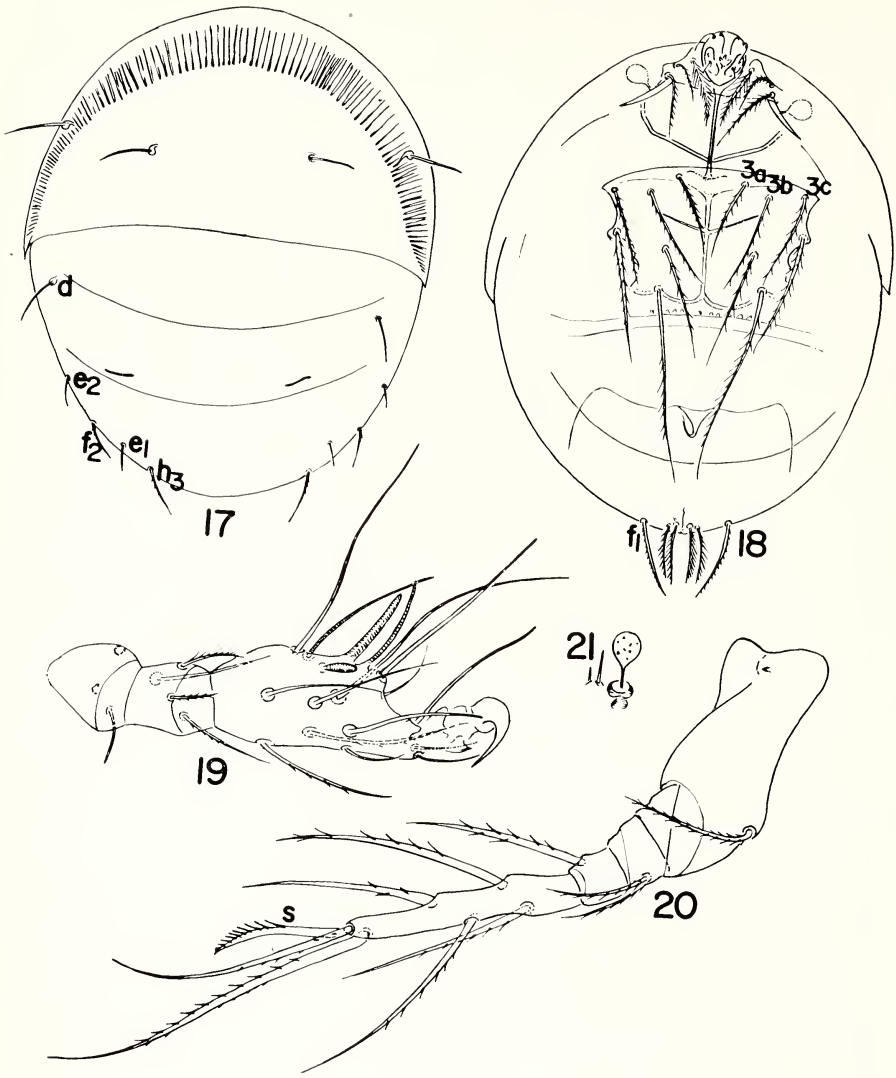


Figs. 13–16. *Scutacarus* (*V.*) *uniformis*, n. sp. 13. Female dorsum. 14. Female venter. 15. Femur, genu, tibiotarsus and solenidia of leg I. 16. Leg IV.

club-shaped; φ_2 similar to ω_2; φ_1 slightly swollen distally; longer than φ_2. Tarsus II solenidion ω_1 same form as ω_1 of tibiotarsus I except smaller. Tibia II and III solenidion φ_1 small, club-shaped, that on tibia III much smaller. Seta *d* of genu of leg I simple. Leg IV as in figure 16. Tibiotarsus very short, shorter than its basal width, with 7 sparsely barbed setae except *r*.

Male. Unknown.

Holotype. Female (unique), Farmingdale, Long Island, New York, June 30, 1973, from a bird nest collected by M. D. Delfinado and M. J. Abbatiello.



FIGS. 17–21. *Scutacarus* (*S.*) *fimetarius*, n. sp. 17. Female dorsum. 18. Female venter. 19. Femur, genu, tibiotarsus and solenidia of leg I. 20. Leg IV. 21. Sensillus prodorsal setae *pd1* and *pd2*.

Remarks. S. **uniformis** n. sp. is similar to **affinis**, n. sp. and **contiguus**, n. sp., differing essentially by the relative lengths of the setae on the dorsum of idiosoma and on tibiotarsus of leg IV, and by the size and the form of solenidion ω_2 of tibiotarsus I. *S.* **uniformis** has uniformly short dorsal setae and much shorter setae on the tibiotarsus of leg IV than any other species known in the group. Also solenidion ω_2 is shorter than that of *affinis* or *contiguus*.

Subgenus *Scutacarus* Gros

Scutacarus (*Scutacarus*) **fimetarius**, n. sp.

(Figures 17–21)

Female (*Holotype*). Idiosoma 255 μ long, 217 μ wide, elliptical.

Dorsum (fig. 17). Sensillus capitate, spiculate; prodorsal setae spinelike, *pd2* about ½ as long as *pd1*. Setae *c1* and *c2* strong, simple; *c1* shorter than *c2*; *d* as long as *c1*, simple; *e1* as long as *e2*, fairly weak, simple; *f2* shorter than *f1*, barbed; *f1* strongest of dorsal setae, barbed.

Venter (fig. 18). Anterior coxisternal plate not as sclerotized as posterior coxisternal plate. Apodeme 2 poorly developed, appearing as weak, curved line below apodeme 1. Apodeme 4 incomplete, seen as short lateral extensions of posterior apodeme (*apsp*) (in some paratype specimens apodeme 4 may appear faintly connected to acetabula of leg III). Sternal apodemes (*apsa*, *apsp*) strong, the posterior end of *apsp* extending to acetabula of leg IV. Epimeral setae *1a* large, thickly barbed; *1b* and *2a* similar to *1a* but moderately barbed and not as large; *2b* saberlike, smooth; *3a*, *3b* and *3c* as long as *4a*, barbed; *4a* inserted anterior to *4b*, barbed; *4c* as strong as *4b* but shorter; *4b* very long but not reaching bases of caudal setae. Caudal setae *h1* and *h2* plumose, approximate at their origins; *h3* sparsely barbed, distant. Tibiotarsus of leg I as in figure 19. Solenidia ω_2 and φ_1 very long, slender; ω_1 stout, tapering distally; φ_2 small, club-shaped. Tarsus II solenidion ω_1 same form as ω_1 of tibiotarsus I but smaller. Tibia II and III solenidion φ_1 small, club-shaped, same size. Leg IV as in figure 20, with long, slender tibiotarsus, about as long as length of trochanter, with 7 setae. Seta *s* very short, about ½ as long as *r* and strongly serrate at distal half.

Male. Unknown.

Holotype. Female, Coeymans, Rt. 143, New York, July 7, 1974, from pasture manure collected by M. D. Delfinado.

Paratypes. 53 females, with same data as holotype; 35 females, Fran Mushroom Co., Ravena, New York, July 11, 1974, from compost and straw collected by M. D. Delfinado.

Remarks. This species is similar to *S.* **mahunkai**, n. sp. in many respects. Both are characterized in part by having long and slender tibiotarsus IV, very long rodlike solenidia ω_2 and φ_1 of tibiotarsus I, and strongly developed posterior sternal apodeme (*apsp*) connected to the acetabula of leg IV. *S.* **fimetarius**, however, is distinguished in having a poorly developed apodeme 2, small solenidion φ_2 of tibiotarsus I and short epimeral setae *4b*. Also the corresponding apical setae *r*, *s* and *p* of tibiotarsus IV are distinctive in **fimetarius**.

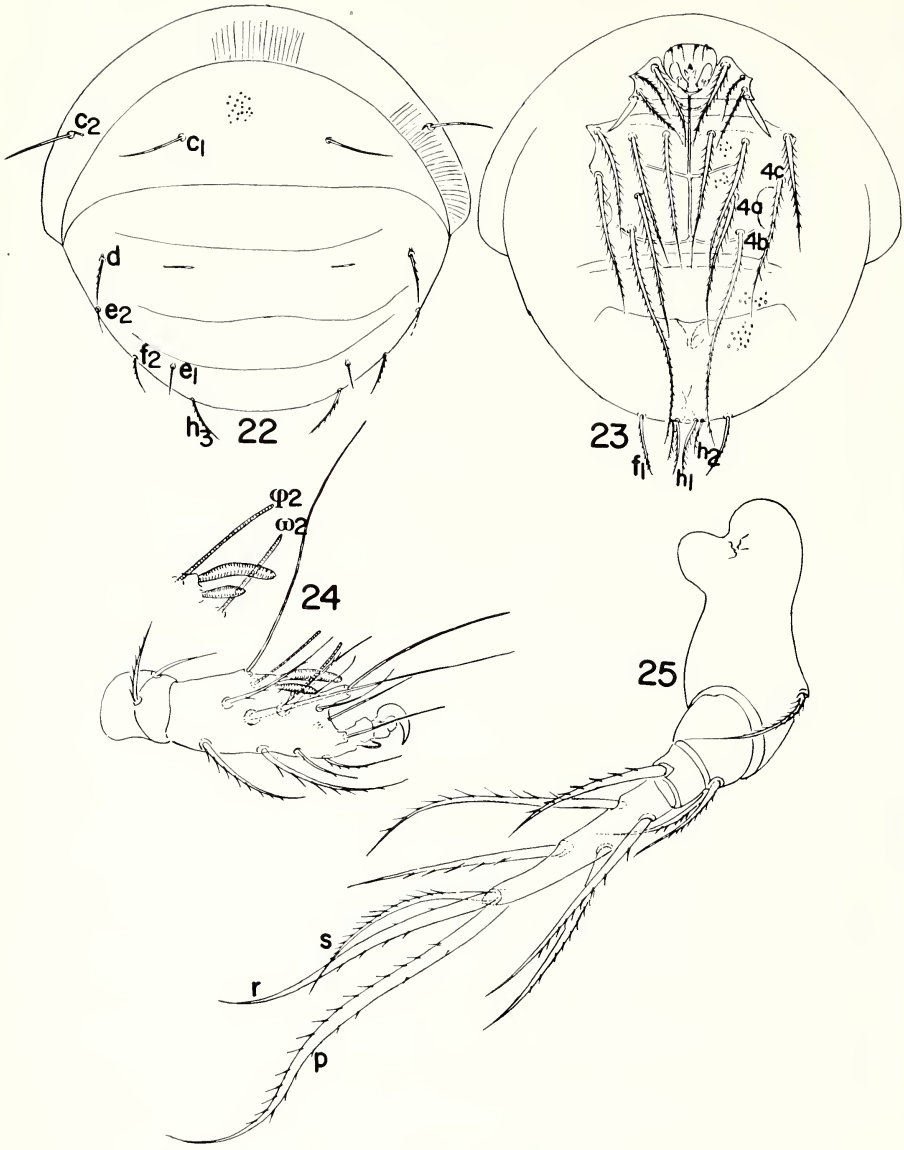
Scutacarus (*Scutacarus*) **mahunkai**, n. sp.

(Figures 22–25)

Female (*Holotype*). Idiosoma 223 μ long, 226 μ wide, broadly elliptical.

Dorsum (fig. 22). Sensillus capitate, spiculate(?); prodorsal setae *pd1* and *pd2* minute, spinelike. Setae *c1* similar to *c2*, strong, simple; *d* as strong as *f2*, barbed; *e1* and *e2* simple, as long as *f2*; *f1* strongest of dorsal setae.

Venter (fig. 23). Anterior and posterior coxisternal plates as in **fimetarius**, n. sp. Apodeme 2 not fully developed, appearing as short lateral extensions of anterior sternal apodeme (*apsa*). Apodeme 4 incomplete, with free ends approaching acetabula of leg III. Sternal



FIGS. 22–25. *Scutacarus* (*S.*) *mahunkai*, n. sp. 22. Female dorsum. 23. Female venter. 24. Genu, tibiotarsus and solenidia of leg I. 25. Leg IV.

apodemes (*apsa*, *apsp*) very strong, especially *apsp* with posterior end extending to acetabula of leg IV. Epimeral setae *1a* large, strong, barbed; *1b* and *2a* similar to *1a* but much smaller; *2b* robust, saberlike, smooth; *3a*, *3b* and *3c* equally long, barbed, arranged in a straight transverse row; *4a* as long as *4c*, inserted anterior to *4b*, barbed; *4b* very long, reaching posteriorly beyond margin of hysterosoma, barbed. Caudal setae

h1, as strong as *h3*, barbed; *h2* shorter than *h1*, sparsely barbed; *h3* distant; *h1* and *h2* approximate at their origins. Tibiotarsus of leg I as in figure 24. Solenidia ω_2 and φ_1 very long, slender; ω_1 stout, large; φ_2 small, club-shaped. Tarsus II solenidion ω_1 same form as ω_1 of tibiotarsus I but smaller. Tibia II and III solendion φ_1 not seen. Leg IV as in figure 25; tibiotarsus long and slender, about as long as length of trochanter, with 7 setae. Seta *s* short about ⅔ as long as *r*, serrate to near base; setae *r* and *p* sparsely serrate.

Male. Unknown.

Holotype. Female (unique), Ausable, Champlain Region, New York, September 14, 1973, taken from weeds mixed with soil on roadside by M. D. Delfinado.

Remarks. *S.* **mahunkai,** n. sp. and **fimetarius**, n. sp. are closely related and appear to belong to the *longitarsus* complex by the long tibiotarsus of leg IV, by the form of the solenidia on tibiotarsus of leg I, and by the position of caudal setae *h1*, *h2* and *h3*. These two species may be separated most easily by the length of the sternal setae *4b* and by the development of apodeme *2*. In **fimetarius** setae *4b* are short, not reaching beyond the posterior margin of the hysterosoma; in **mahunkai** these setae are very long, extending beyond the posterior margin of the hysterosoma. The apodeme *2* in **fimetarius**, is poorly developed, appearing as a thin line joining the acetabula of leg II whereas in **mahunkai** apodeme *2* appears as very short, thick lateral extensions of the sternal apodeme (*apsp*) and is free from the acetabula of leg II.

Scutacarus (*Scutacarus*) *acarorum* (Goeze)
(Figures 26–31)

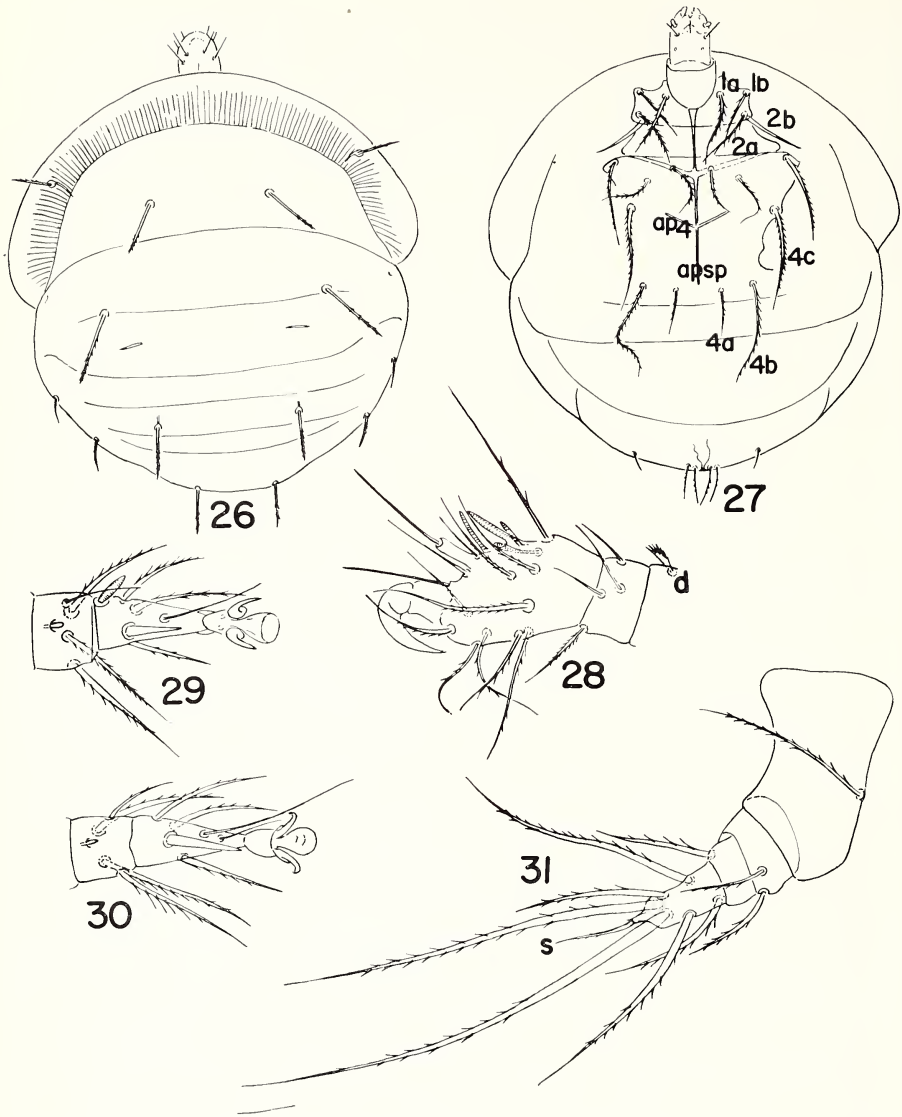
Acarus acarorum Goeze, 1780, Neu entdeckte Theile an Ins., p. 97 (cited from Oudemans, 1937).

Scutacarus acarorum, Karafiat, 1959, Beitr. Syst. u. Ökol. Mitteleurop. Acarina 1(2): 651.

Female. Idiosoma 223 μ long, 220 μ wide, elliptical.

Dorsum (fig. 26). Sensillus capitate, with a few spicules; prodorsal setae *pd1* and *pd2* not seen. Setae *c1* longer and stronger than *c2*, barbed; *d* strongest and longest of dorsal setae; *e1* as strong and as long as *f1*, barbed; *e2* and *f2* short, the former simple and weak, the latter sparsely barbed and stronger.

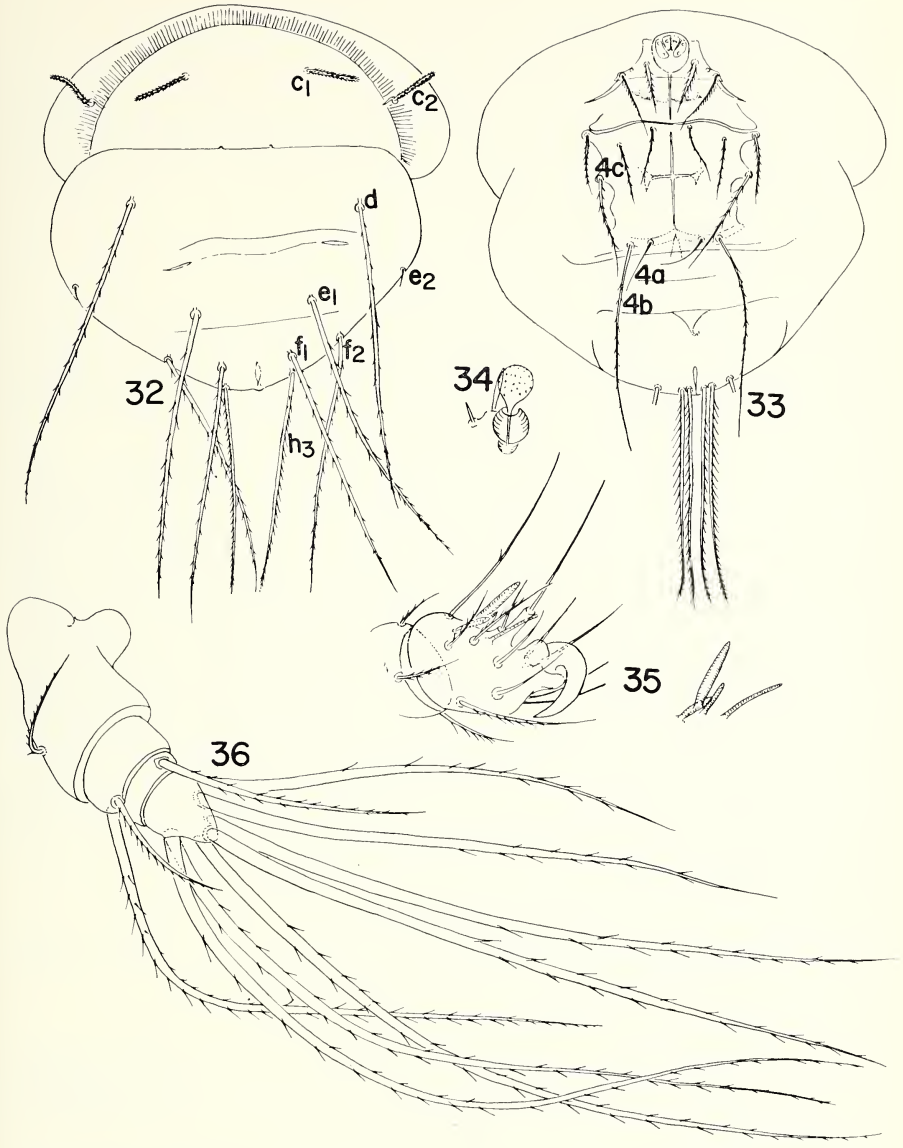
Venter (fig. 27). Coxisternal plates finely punctate. Apodeme *2* poorly developed, appearing as thin line extending to acetabula of leg II. Posterior sternal apodeme (*apsp*) strong, with free end reaching posteriorly to level of bases of setae *4a*. Apodeme 4 incomplete, free; a small secondary apodeme present below *ap4*. Epimeral setae *1a* strong, barbed; *1b* and *2a* similar to *1b* except smaller; *2b* daggerlike, smooth; *3a* short, as long as *3b*, barbed; *3c* as strong as *4c* but shorter; *4a short*, about ½ as long as *4b*, sparsely barbed at middle. Caudal setae *h1* similar to *h2*, slender, sparsely barbed, approximate at their origins; *h3* very small, weak, simple, distant. Tibiotarsus, femur and genu of leg I as in figure 28. Solenidion ω_2 slender, straight; ω_1 stout, tapered distally; φ_1 and φ_2 short, club-shaped. Seta *d* of femur I short, broadened and pectinate distally. Tarsus II (fig. 29) solenidion ω_1 stout. Tibia II and III (fig. 30) solenidion φ_1 very small, peglike. Leg IV as in figure 31. Tibiotarsus elongate, about twice as long as its basal width, with 7 setae, characteristically produced apically bearing a very short, slender seta *s*.



Figs. 26–31. *Scutacarus* (*S.*) *similis*, n. sp. 26. Female dorsum. 27. Female venter. 28. Femur, genu and tibiotarsus I. 29. Tibia and tarsus of leg II. 30. Tibia and tarsus of leg III. 31. Leg IV.

Male. Unknown.

Material examined. 1 female, Kerner, New York, June 1928, taken from a bumble bee by M. D. Delfinado (on same slide with paratypes of *Kuzinia americana* Baker and Delfinado); 1 female, 1.45 km. NE of Varna, New York, September 8, 1973, taken from



Figs. 32–36. *Scutacarus* (*S.*) *formosus*, n. sp. 32. Female dorsum. 33. Female venter. 34. Sensillus and prodorsal setae *pd1* and *pd2*. 35. Genu, tibiotarsus and solenidia of leg I. 36. Leg IV.

a bumble bee by B. OConnor; 1 female, Jamestown, New York, August 31, 1940, from petiole of *Bombus americanorum* by R. E. Crabill.

Remarks. S. acarorum (Goeze) may be distinguished in having an elongate tibiotarsus IV which is produced apically and bears a short, slender seta *s*, and by the characteristic development of seta *d* on the femur of leg I. The latter feature is also found in the *baculitarsus* complex, but the tibiotarsus IV is much more elongate and the caudal setae *h1*, *h2* and *h3* are well separated at their origins.

Scutacarus (*Scutacarus*) **formosus**, n. sp.
(Figures 32–36)

Female (*Holotype*). Idiosoma 230 μ long, 242 μ wide, broadly obovate.

Dorsum (fig. 32). Sensillus capitate, spiculate; prodorsal setae spinelike, *pd1* more robust and longer than *pd2* (fig. 34). Setae *c1* as long as *c2* stout, thickly covered with short bristles; *d*, *e1*, *f1* and *f2* extremely long, about ⅔ as long as length of idiosoma, sparsely barbed; *e2* minute, simple.

Venter (fig. 33). Coxisternal plates well sclerotized, finely punctate. Apodeme 2 poorly developed, appearing as thickened curved line joining acetabula of leg II. Apodeme 4 incomplete, seen as short, lateral extensions of sternal apodeme (*apsp*); a small secondary apodeme fairly discernible below *ap4*. Posterior sternal apodeme (*apsp*) very strong, with posterior end extending to acetabula of leg IV. Epimeral setae *1a* large, pectinate; *1b* small, barbed; *2a* as long as *1a*, slender, barbed; *2b* large, saberlike; *3a*, *3b* and *3c* same length, sparsely barbed; *4a* very short, simple; *4b* very long, extending beyond margin of hysterosoma; *4a* and *4b* arranged in a straight transverse row along margin of posterior coxisternal plate. Caudal setae *h1*, *h2* and *h3* very long, about as long as length of dorsal setae *f1*, barbed; *h1* and *h2* approximate at their origins; *h3* distant. Tibiotarsus and solenidia of leg IV as in figure 35. Solenidion ω_2 long and slender; ω_1 large; φ_1 small, club-shaped; φ_2 as long as φ_1, slender. Tarsus II solenidion ω_1 club-shaped, slightly smaller than ω_1 of tibiotarsus I. Tibia II and III solenidion φ_1 not seen. Leg IV as in figure 36. Tibiotarsus slightly longer than its basal width, with 7 very long setae; seta *s* as long as *r* and *p*.

Male. Unknown.

Holotype. Female, Rt. 9, New Baltimore, New York, July 16, 1974, from pine debris collected by M. D. Delfinado.

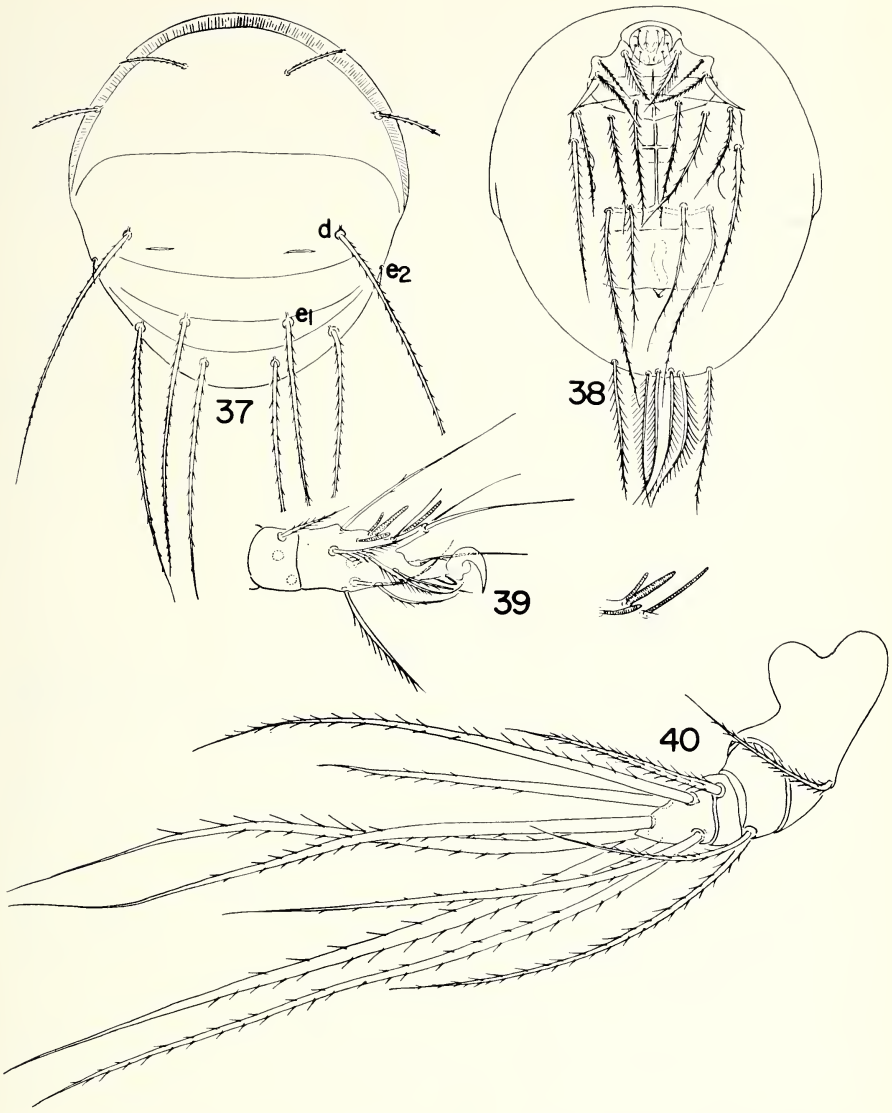
Paratype. 1 female, with same data as holotype.

Remarks. S. **formosus**, n. sp. is similar to *S.* **pectinatus**, n. sp. in having extremely long dorsal setae *d*, *e1*, *f1* and *f2* and epimeral setae *4b*, and tiny setae *e2*. But **formosus** can be easily recognized by the uniformly developed caudal setae *h1*, *h2* and *h3*, and by the stout dorsal setae *c1* and *c2*.

Scutacarus (*Scutacarus*) **pectinatus**, n. sp.
(Figures 37–40)

Female (*Holotype*). Idiosoma 217 μ long, 191 μ wide, obovate.

Dorsum (fig. 37). Sensillus capitate, spiculate (?); prodorsal setae spinelike *pd1* as long as *pd2* but more robust. Type of dorsal setae as in **formosus**, n. sp. except *c1* and *c2* moderately barbed and *f1* stronger; *e2* tiny as in **formosus**.



Figs. 37–40. *Scutacarus* (*S.*) *pectinatus*, n. sp. 37. Female dorsum. 38. Female venter. 39. Genu, tibiotarsus and solenidia of leg I. 40. Leg IV.

Venter (fig. 38). Posterior coxisternal plate more sclerotized than anterior coxisternal plate, punctate. Apodeme 2 poorly developed as weak curved line connected to acetabula of leg II. Apodeme 4 incomplete, free. Posterior sternal apodeme (*apsp*) strong, connected posteriorly to acetabula of leg IV. Epimeral setae *1a* large, strongly plumose; *1b* smaller than *2a*, barbed; *2b* large, saberlike, smooth; *3a* as long as *3b* and *3c*,

strong, barbed; *4a* as strong as *4b*, long, reaching bases of caudal setae *h1* and *h2*, barbed; *4b* very long, extending beyond margin of hysterosoma, barbed; *4c* similar to *4b* but shorter. Caudal setae *h1* and *h2* well developed, thickly feathered, approximate at their origins; *h3* as long as *h1* and *h2*, barbed, distant. Tibiotarsus of leg I as in figure 39. Solenidion ω_2 long, slender, rodlike; ω_1 stout, shorter than ω_2; φ_1 club-shaped, longer than slender φ_2. Tarsus II solenidion ω_1 stout, club-shaped. Tibia II solenidion φ_1 similar to ω_1 of tarsus II but slender and shorter. Tibia III solendion φ_1 not seen. Leg IV as in figure 40; tibiotarsus slightly longer than its basal width; seta *s* as long as setae *r* and *p*.

Male. Unknown.

Holotype. Female, near Flanders, Long Island, New York, July 16, 1973, from litter collected by M. D. Delfinado and M. J. Abbatiello.

Paratypes. 13 females with same data as holotype; 3 females, Adirondack Mts., Champlain Region, September 15, 1973, taken from soil and pine litter on roadside along Rt. 87 by M. D. Delfinado.

Remarks. The large, thickly feathered caudal setae *h1* and *h2* will readily separate **pectinatus**, n. sp. from its closely related species, **formosus**, n. sp.

Scutacarus (*Scutacarus*) **communis**, n. sp.
(Figures 41–44)

Female (*Holotype*). Idiosoma 255 μ long, 243 μ wide, obovate.

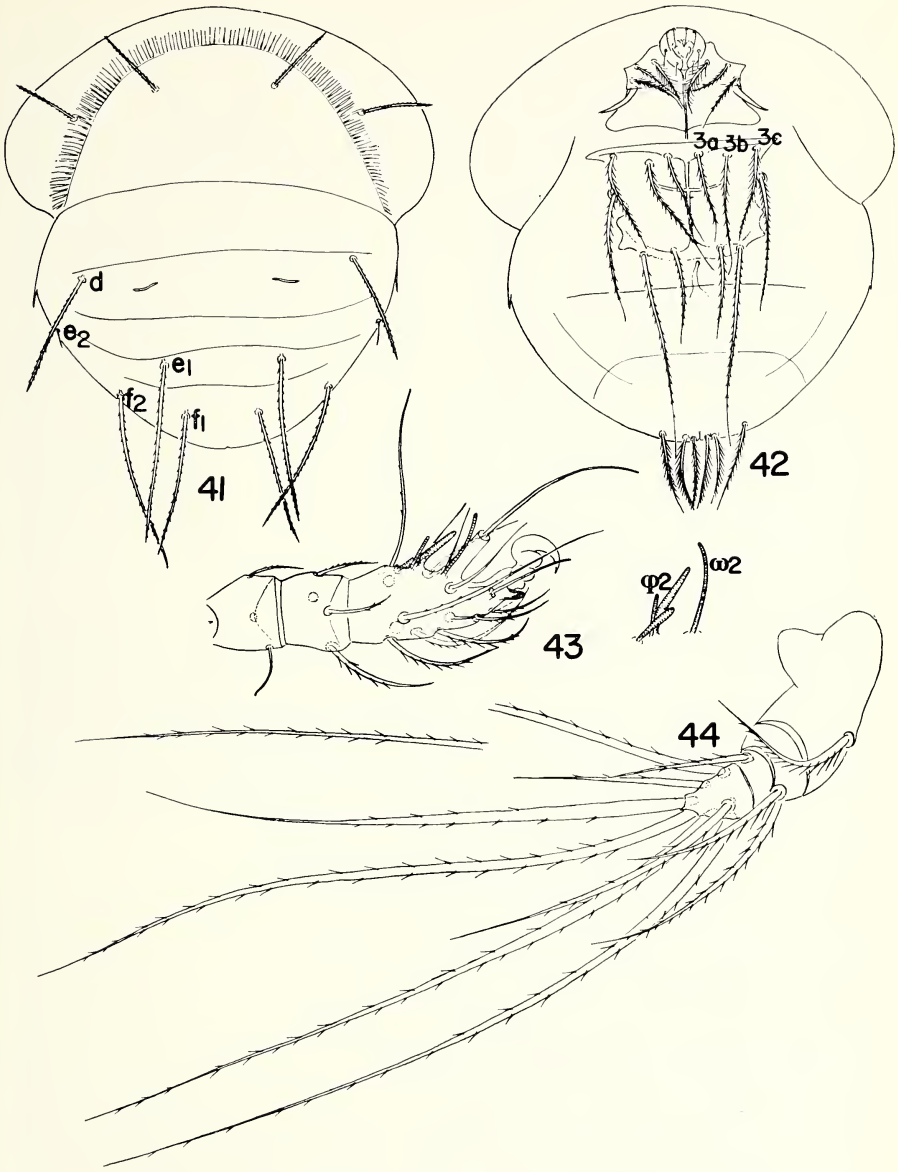
Dorsum (fig. 41). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* strong, spinelike. Type of dorsal setae as in **pectinatus**, n. sp. except setae *d*, *e1*, *f1* and *f2* shorter, about ½ as long as idiosoma; *e2* tiny as in **pectinatus**.

Venter (fig. 42). Coxisternal plates well sclerotized, punctate. Apodeme 2 not developed, hardly discernible. Apodeme 4 incomplete, seen as short lateral extensions of posterior sternal apodeme (*apsp*). Posterior sternal apodeme (*apsp*) strong, with posterior and extending to acetabula of leg IV; a small secondary apodeme present below *ap4*. Epimeral setae *1a* large, plumose; *1b* similar to *2a*, barbed; *2b* large, saberlike; *3a* slightly longer than *3b* and *3c*, barbed; *4a* short, about ½ as long as *4b*, barbed; *4b* very long, reaching beyond posterior margin of hysterosoma, barbed. Caudal setae *h1* and *h2* feathered, shorter than *h3*, approximate at their origins; *h3* barbed, distant. Tibiotarsus of leg I as in figure 43. Solenidion ω_2 very long, slender; ω_1 stout, almost tapered distally; φ_2 small, rodlike; φ_1 club-shaped. Tarsus II solenidia ω_1 similar to ω_1 of tibiotarsus I. Tibia II solenidion φ_1 very small, club-shaped. Tibia III solenidion φ_1 not seen. Leg IV as in figure 44. Tibiotarsus slightly longer than its basal width; seta *s* shorter than *p* and *r*.

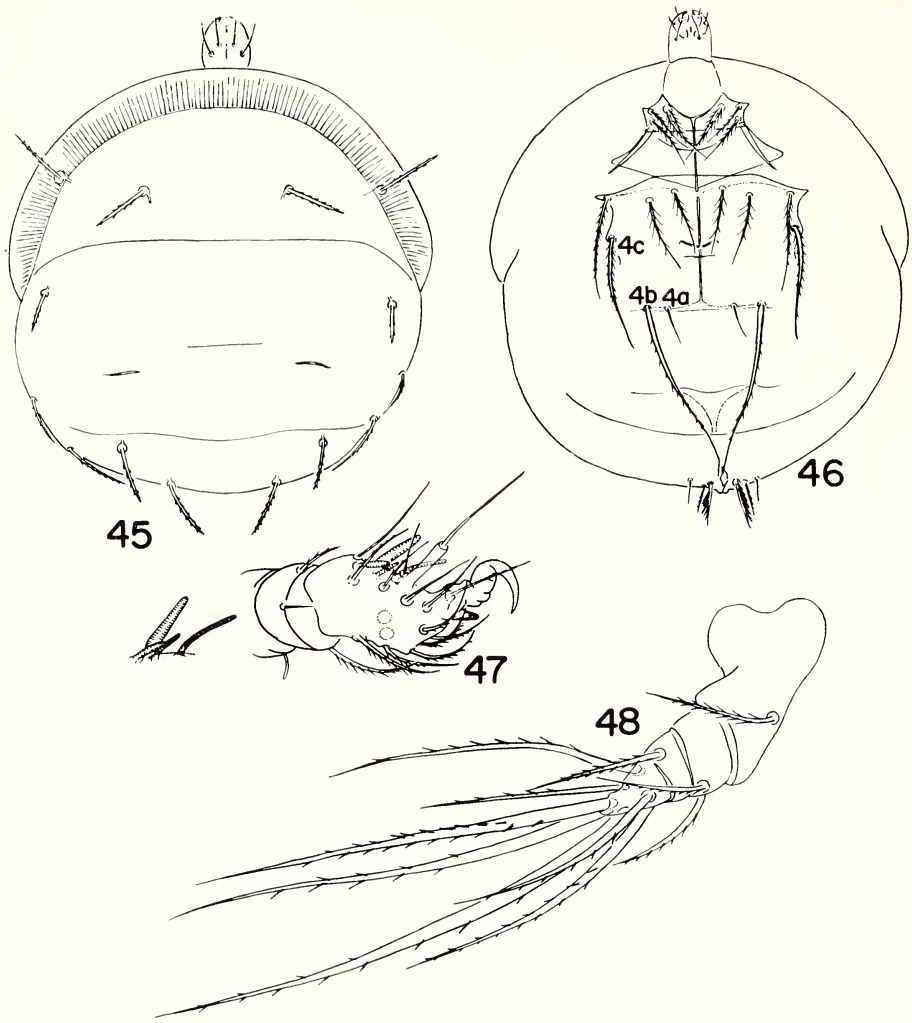
Male. Unknown.

Holotype. Female, Ausable, Champlain Region, New York, September 14, 1973, collected from moss by M. D. Delfinado.

Paratypes. 11 females with same data as holotype; 3 females, near Bolton Landing, Lake George, New York, August 8, 1973, collected from bark and soil at base of a tree; 1 female, Minerva Lake, Adirondack Mts., New York, September 29, 1973, collected from moss; 2 females, Crescent, Mohawk Valley, New York, October 4, 1973, taken from rotten log; 2 females, boggy thickets 5 mi east of Taborton, Rensselaer County, New York,



Figs. 41–44. *Scutacarus* (*S.*) *communis*, n. sp. 41. Female dorsum. 42. Female venter. 43. Femur, genu, tibiotarsus and solenidia of leg I. 44. Leg IV.



FIGS. 45–48. *Scutacarus* (*S.*) *pedestris*, n. sp. 45. Female dorsum. 46. Female venter. 47. Genu, tibiotarsus and solenidia of leg I. 48. Leg IV.

August 5, 1974, taken from liverwort; 2 females, Cedarville Swamp, Herkimer County, New York, August 8, 1974, taken from liverwort. All mite specimens were collected by means of Berlese funnels by M. D. Delfinado. The liverwort material was collected by Mr. S. J. Smith (New York State Museum & Science Service at Albany).

Remarks. This new species is related to **pectinatus**, n. sp. and **formosus**, n. sp. *S.* **communis**, n. sp. differs by having much shorter dorsal setae *d*, *e1*, *f1* and *f2* and caudal setae *h1* and *h2*. Also seta *s* of tibiotarsus I is shorter than *p* and *r*; these setae are equal in length in **pectinatus** and **formosus**.

Scutacarus (*Scutacarus*) **pedestris**, n. sp.
(Figures 45–48)

Female (*Holotype*). Idiosoma 146 μ long, 140 μ wide, elliptical.

Dorsum (fig. 45). Sensillus, capitate, spiculate(?); prodorsal setae *pd1* and *pd2* not seen. All dorsal setae barbed and short; *c1* as strong and as long as *c2*; *d* similar to *e1*, *f1* and *f2* except much shorter; *e2* fairly slender and short.

Venter (fig. 46). Coxisternal plates developed, thinly sclerotized, finely punctate. Apodeme 2 poorly developed, appearing as thin curved line joining acetabula of leg II. Apodeme 4 incomplete, as short lateral extensions of sternal apodeme (*apsp*); a small secondary apodeme present below *ap4*. Sternal apodeme (*apsp*) strong, extending posteriorly to acetabula of leg IV. Epimeral setae *1a* and *2a* large, plumose; *1b* small, sparsely plumose; *2b* saberlike, smooth; *3a* similar to *3b*, barbed; *4c* as stout as *4b* but shorter, barbed; *4a* very short, weak, simple; *4b* long, almost reaching posterior margin of hysterosoma. Caudal setae *h1* large, thickly feathered; *h2* slender, finely pectinate; *h3* short, weak, simple, distant; *h1* and *h2* approximate at their origins. Tibiotarsus of leg I as in figure 47. Solenidion ω_1 stout, as long as slender solenidion ω_2; φ_1 small, as long φ_2. Tarsus II solenidion ω_1 same form as ω_1 of tibiotarsus I except stouter and shorter. Tibia II and III solenidion φ_1 small, club-shaped, that on tibia slightly smaller. Leg IV as in figure 48. Tibiotarsus conical, longer than its basal width, with 7 setae. Seta *s* slightly shorter than *p* and *r*.

Male. Unknown.

Holotype. Female, Cooperstown, New York, August 26, 1973, taken from debris near base of a tree by M. D. Delfinado.

Paratypes. 2 females, with same data as holotype.

Remarks. The very short, weak and simple epimeral setae *4a*, the uniformly short dorsal setae of idiosoma, and the small solenidia φ_1 and φ_2 are characteristic of this new species.

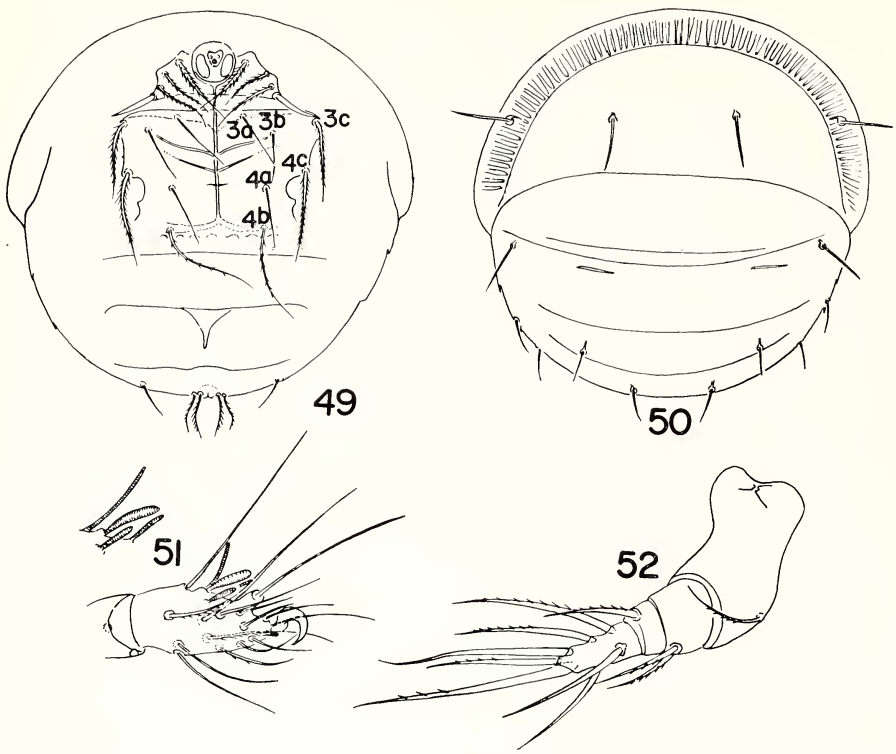
Scutacarus (*Scutacarus*) **notabilis** n. sp.
(Figures 49–52)

Female (*Holotype*). Idiosoma 140 μ long, 143 μ wide, elliptical.

Dorsum (fig. 50). Sensillus capitate, covered with spicules; prodorsal setae *pd1* and *pd2* minute, hardly discernible. All dorsal setae simple; *c1* and *c2* as long and as strong as *d*; *e1*, *e2*, *f1* and *f2* slender, uniformly short, shorter than *d*.

Venter (fig. 49). Coxisternal plates well sclerotized, punctate. Apodeme 2 poorly developed, connected to acetabula of leg II. Apodeme 4 strong, but faintly connected to acetabula of leg III. Sternal apodeme (*apsp*) strong, extending posteriorly to acetabula of leg IV. Epimeral setae *1a* large, serrate; *1b* similar to *2a* slender, barbed; *2b* saberlike, smooth; *3c* and *4c* strong, barbed; *4a* simple, about ⅔ as long as, and inserted anterior to *4b*; *4b* slightly longer than *4c*, barbed. Tibiotarsus of leg I as in figure 51, solenidion ω_2 short, slender; ω_1 stout, club-shaped; φ_2 very long, slender; φ_1 short, club-shaped, about ½ as long as φ_2. Tarsus II solenidion ω_1 as large as ω_1 of tibiotarsus I. Tibia II and III solenidion φ_1 not seen due to poor orientation of specimen. Leg IV as in figure 52. Leg setae mostly short, sparsely barbed or smooth. Tibiotarsus twice as long as its basal width, with 7 setae. Seta *s* shorter than *r* and *p*; seta *r* smooth.

Male. Unknown.



FIGS. 49–52. *Scutacarus* (*S.*) *notabilis*, n. sp. 49. Female venter. 50. Female dorsum. 51. Genu, tibiotarsus and solenidia of leg I. 52. Leg IV.

Holotype. Female, along stream bank, Ilion Gulf, Herkimer County, New York, August 5, 1974, taken from moss, *Drepanocladus*, sp. by M. D. Delfinado.

Paratype. 1 female, with same data as holotype. The moss was collected and identified by Mr. S. J. Smith.

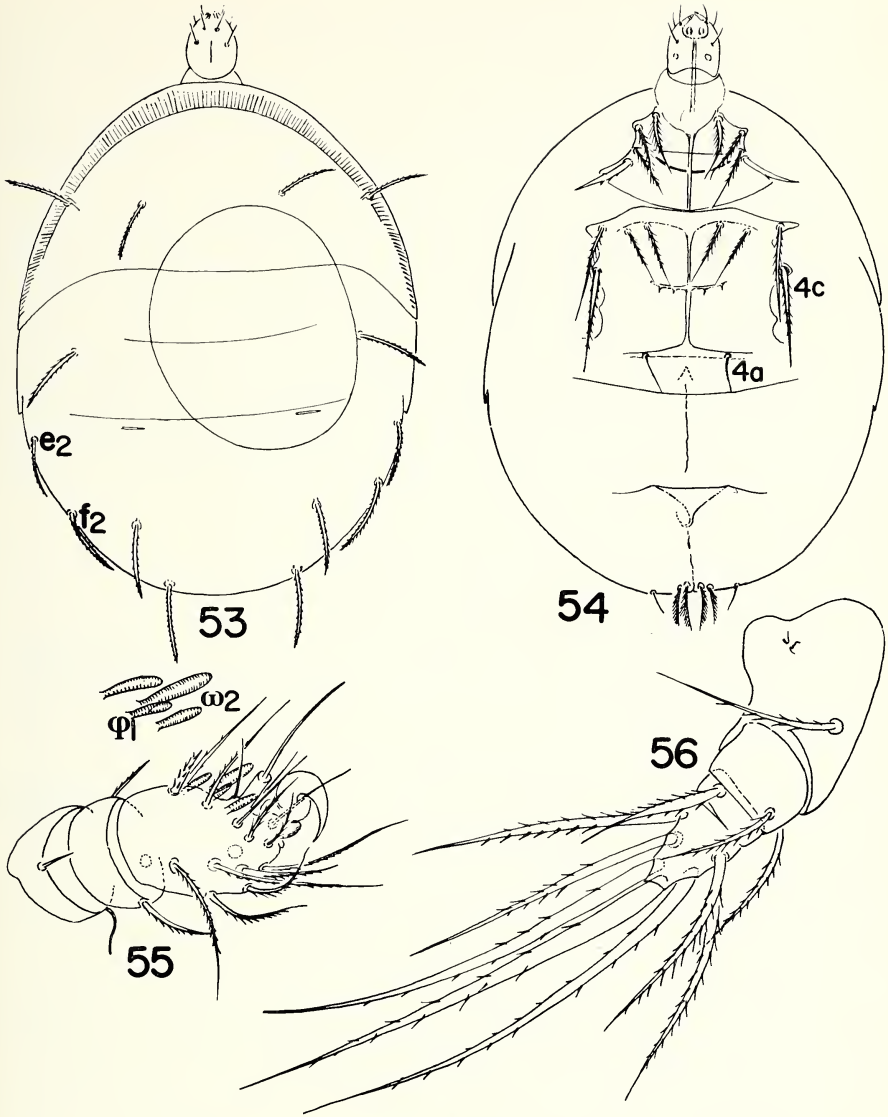
Remarks. This is a distinctive species in that all the dorsal setae on idiosoma are simple; the epimeral setae *4a* are displaced anterior to *4b*; the solenidion φ_2 is unusually long and slender, and the setae on the leg IV are mostly short.

Scutacarus (*Scutacarus*) **grosi**, n. sp.
(Figures 53–56)

Female (*Holotype*). Idiosoma 223 μ long, 179 μ wide, elongate elliptical.

Dorsum (fig. 53). Sensillus capitate, surface rough; prodorsal setae *pd1* and *pd2* strong, spinelike. All dorsal setae short, of uniform type and thickness, barbed.

Venter (fig. 54). Coxisternal plates sclerotized, minutely punctate. Apodeme 2 well developed, strong, joining acetabula of leg II. Apodeme 4 strong but incomplete; a small secondary apodeme present immediately below *ap4*. Sternal apodeme (*apsp*) complete,



Figs. 53–56. *Scutacarus* (*S.*) *grosi*, n. sp. 53. Female dorsum. 54. Female venter. 55. Genu, tibiotarsus and solenidia of leg I. 56. Leg IV.

posteriorly joining acetabula of leg IV. Epimeral setae *1a* similar to *1b* and *2a*, barbed; *2b* saberlike, with 1–3 median serrations; *3a* and *3b* as long and as strong as *3c*, barbed; *4c* very strong, barbed; *4a* small, simple; *4b* absent. Caudal setae *h1* as long as *h2*, feathered, approximate at their origins; *h3* simple, distinct. Tibiotarsus of leg I as in figure 55. Solenidion ω_2 short, as long as φ_2; ω_1 very large; φ_1 similar to ω_1 but smaller. Tarsus II

solenidion ω_1 large. Tibia II solenidion φ_1 larger than that on tibia III, club-shaped. Leg IV as in figure 56. Tibiotarsus longer than its basal width, with 7 setae. Seta *r* as long as *s* and *p* but *s* more robust.

Male. Unknown.

Holotype. Female, Heckscher Park, Long Island, New York, June 15, 1973, from leaf litter collected by M. D. Delfinado.

Paratypes. 1 female, same data as holotype and on same slide; 3 females, Rt. 87, Champlain Region, New York, August 15, 1973, from debris; 2 females, Newcomb, Adirondack Mts., August 27, 1973, from tree hole debris and rotten bark, all collected by M. D. Delfinado; 1 female, Patridge Run State Grant Area, New York, June 21, 1970, from nest of field sparrow collected by G. Eickwort.

Remarks. The presence of only 1 pair of posterior epimeral setae *4a* on the venter of the idiosoma relates *grosi,* n. sp. to *S. subterraneus* Oudemans and *S. spinosus* Storkan. But *grosi* differs from *subterraneus* by having 7 setae on tibiotarsus IV and complete posterior sternal apodeme (*apsp*); it is most easily recognized from *spinosus* by the large dorsal setae *e2* and *f2*; these setae are very small "spinelet" in *spinosus*.

Scutacarus (*Scutacarus*) **nearcticus**, n. sp.
(Figures 57–60)

Female (*Holotype*). Idiosoma 283 μ long, 313 μ wide, broadly elliptical.

Dorsum (fig. 57). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* large, spinelike, about as long as length of sensillus. Dorsal setae *c1* as long as *c2,* slender, barbed; *d* as long as *c1* but stronger, barbed; *f1* large, lanceolate, barbed; *e2* and *f2* similar to *f1* but much longer and thicker.

Venter (fig. 60). Coxisternal plates well sclerotized, punctate. Apodeme 2 well developed, joining acetabula of leg II. Apodeme 4 developed, with free ends approaching acetabula of leg IV; a small secondary apodeme present below *ap4*. Epimeral setae *1a*, *1b* and *2a* very strong, pectinate; *2b* large, saberlike, serrate; *3a* and *3b* slender, sparsely barbed; *3c* and *4c* strongest of epimeral setae, pectinate; *4a* slender, with sparse fine barbs; *4b* very long, slender, sparsely barbed, reaching posteriorly beyond margin of hysterosoma. Caudal setae *h1* and *h2* feathered, approximate at their origins; *h3* barbed, as long as *h1* and *h2*, distant. Tibiotarsus of leg I as in figure 59. Solenidion ω_2 long and slender; ω_1 stout, as long as ω_2; φ_1 same form as ω_2 but shorter; φ_2 slightly swollen, about as long as φ_1. Tarsus II solenidion ω_1 stouter and longer than that of tibiotarsus I. Tibia II solenidion φ_1 very small, peglike; that on tibia III not seen. Leg IV as in figure 58. Tibiotarsus twice as long as its basal width, with 7 setae. Seta *s* largest of leg IV setae.

Male. Unknown.

Holotype. Female, Plattsburgh, Champlain Region, New York, August 15, 1973, from humus collected by M. D. Delfinado.

Paratypes. 6 females, with same data as holotype; 4 females, Rt. 87, Champlain Region, August 15, 1973, from debris and moss on a tree trunk collected by M. D. Delfinado.

Remarks. This species most closely resembles *S. crassisetus simplex* (Paoli) from Florida but is readily distinguished by the barbed setae *e2* and *f2* and by the large, lanceolate, barbed setae *f1*. Also the epimeral setae *2b* are serrate, and the sensillus is spiculate.

Scutacarus (*Scutacarus*) **curtus**, n. sp.
(Figures 61–64)

Female (*Holotype*). Idiosoma 198 μ long, 198 μ wide, orbicular.

Dorsum (fig. 61). Sensillus capitate, with a few spicules; prodorsal setae *pd1* and *pd2* not seen. All dorsal setae short, barbed, approximately of same length; *c1*, *c2* and *d* heavier and stronger than others.

Venter (fig. 62). Coxisternal plates sclerotized, punctate. Apodeme 2 well developed and joined to acetabula of leg II. Apodeme 4 short, free; a weak secondary apodeme present below *ap4*. Sternal apodeme (*apsp*) free, not connected to acetabula of leg IV. Epimeral setae *1a* strong, pectinate; *1b* and *2a* less robust than *1a*, pectinate; *2b* saberlike, smooth; *3a* shorter than *3b*, sparsely barbed; *3c* as long as *3b*, strong, barbed; *4c* strongest of posterior epimeral setae, barbed; *4a* short, slender; *4b* about twice as long as *4a*, both sparsely barbed. Caudal setae *h1* and *h2* feathered, approximate at their origins; *h3* very small, simple, distant. Tibiotarsus of leg I as in figure 63. Solenidion ω_2 long, slender, straight; ω_1 stout, shorter than ω_2; φ_2 club-shaped, about as long as slender φ_1. Tarsus II solenidion ω_1 stouter than that of tibiotarsus I but shorter. Tibia II and III solenidion φ_1 small, club-shaped. Leg IV as in figure 64. Tibiotarsus slightly longer than its basal width, with 6 setae. Seta *r* very short, ¼ as long as *p*; *s* shorter than *p*.

Male. Unknown.

Holotype. Female, Mohawk River bank, Crescent, New York, October 4, 1973, from debris under a rotting log collected by M. D. Delfinado.

Paratype. Female, Plattsburgh, Champlain Region, August 15, 1973, from humus collected by M. D. Delfinado.

Remarks. The very short seta *r* on tibiotarsus of leg IV is characteristic for *S.* **curtus**, n. sp.

Genus *Imparipes* Berlese

Imparipes Berlese, 1904, Zool. Anz. 27: 22. Type-species, *Imparipes histricinus* (sic) Berlese, 1904, by monotypy.

This genus generally resembles *Scutacarus* but can easily be recognized by having 5-segmented leg IV: distinct tibia and tarsus; 5–6 setae on tarsus, and usually elongate pretarsus. Claws and empodium are usually present. Leg I is 4-segmented and may or may not have claws. Only the females are known.

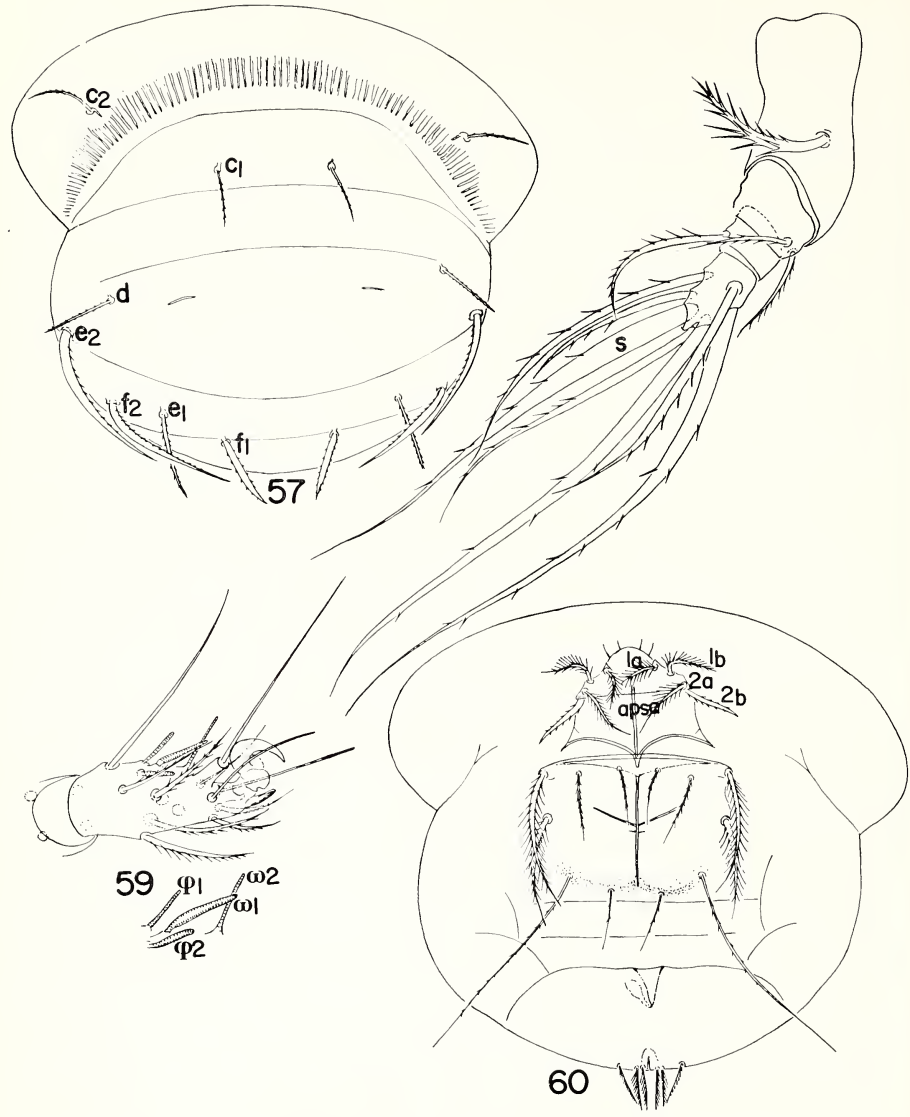
Three species have previously been reported from North America. Eight species and 2 subspecies are described herein, of which 8 are new.

Mahunka (1965) in his identification key of the genera of Scutacaridae recognized three subgenera of *Imparipes* based on what we believe to be trivial characters of tarsus IV. And because the use of subgeneric category, at present, is very confused and has little purpose except to clarify keys, we have not used subgenera of species groups in this paper.

Imparipes **longitarsus**, n. sp.
(Figures 65–68)

Female (*Holotype*). Idiosoma 236 μ long, 198 μ wide, obovate.

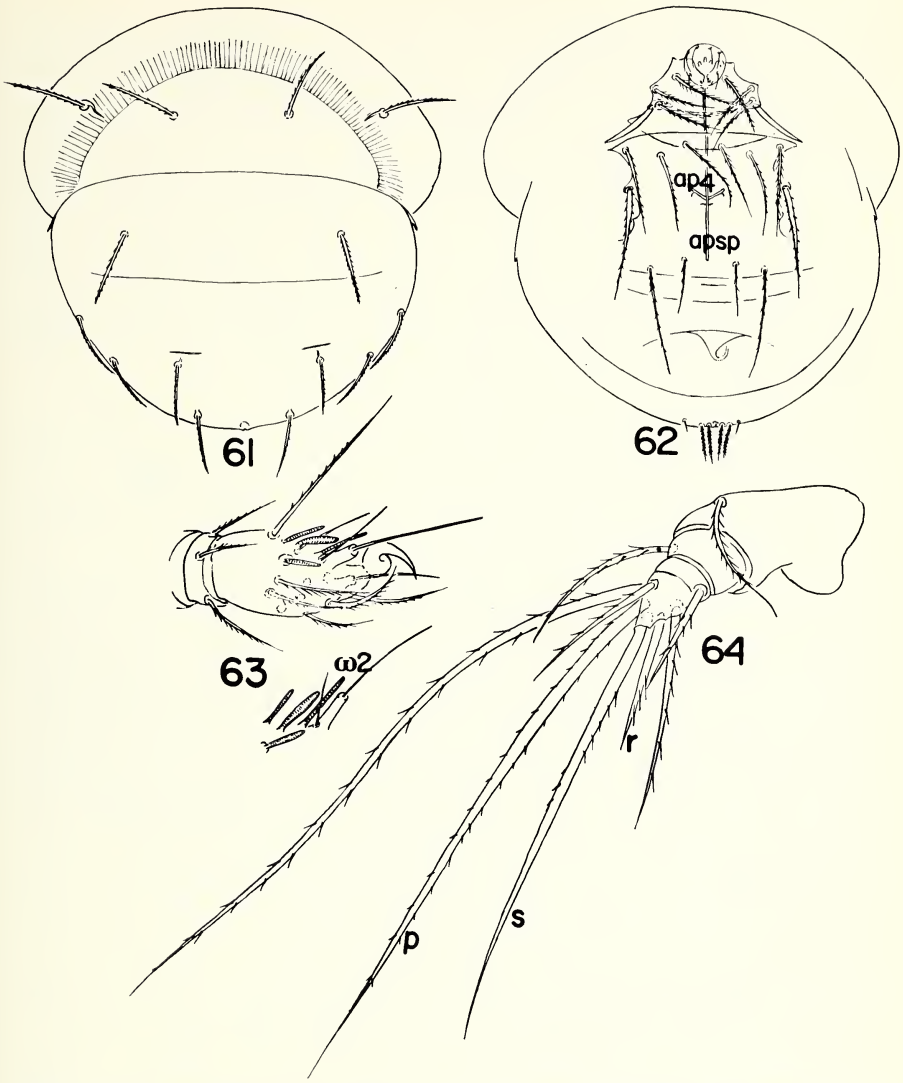
Dorsum (fig. 65). Sensillus capitate, with a few spicules; prodorsal setae spinelike, *pd1* larger and longer than *pd2*. All dorsal setae uniformly barbed. Setae *c1* as long as



FIGS. 57–60. *Scutacarus* (*S.*) *nearcticus*, n. sp. 57. Female dorsum. 58. Leg IV. 59. Tibiotarsus and solenidia of leg I. 60. Female venter.

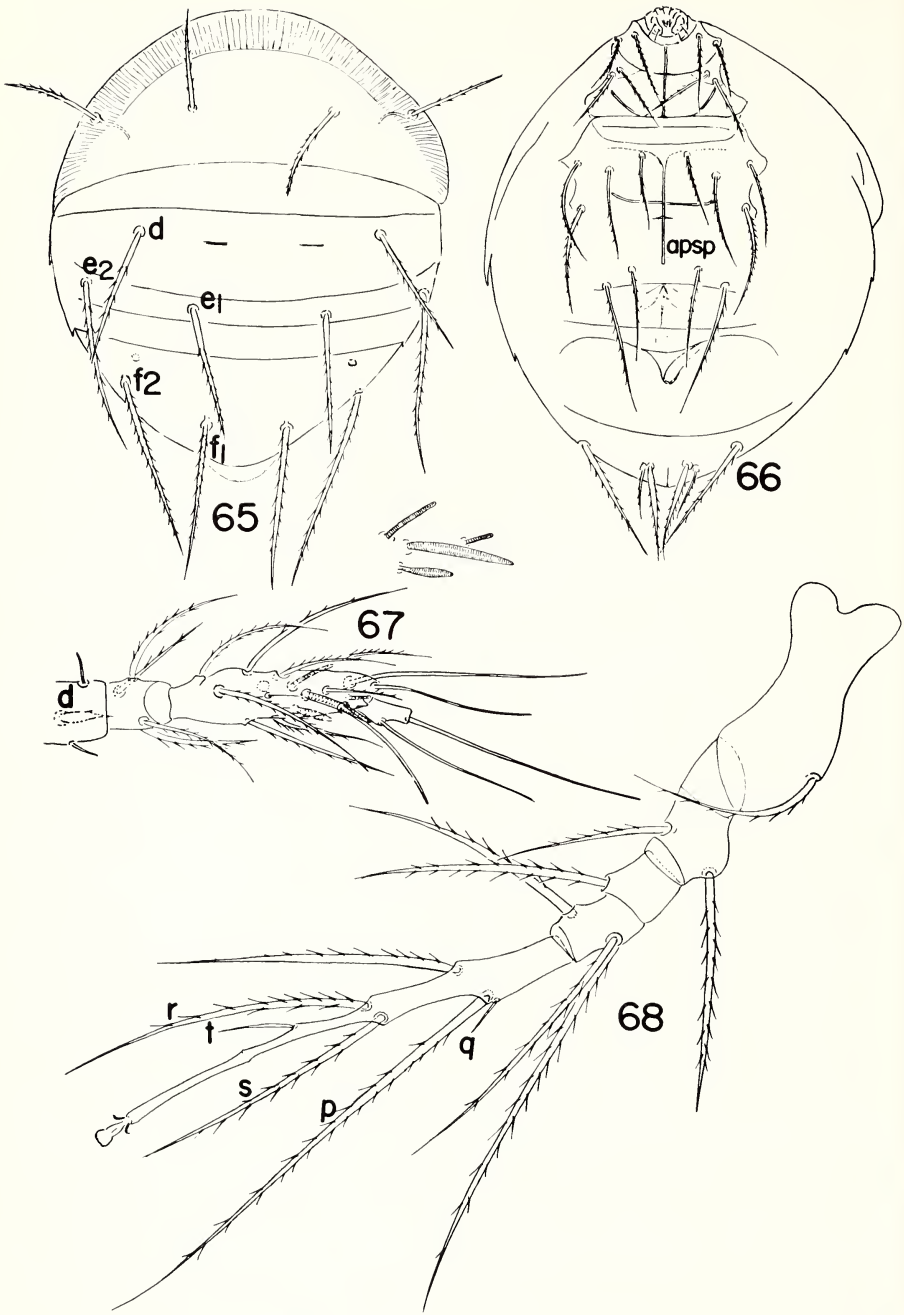
c2, strong; *d* as long *e1*, strong, longer than *c1* and *c2*; *e2* and *f1* as long as *f2*, longer than *d* and *e1*.

Venter (fig. 66). Coxisternal plates poorly sclerotized. Apodeme 2 developed, straight, joining acetabula of leg II. Apodeme 4 free, not joining acetabula of leg III. Posterior sternal apodeme (*apsp*) free. Epimeral setae *1a*, *1b* and *2a* slender, barbed; *2b* similar to



Figs. 61–64. *Scutacarus* (*S.*) *curtus*, n. sp. 61. Female dorsum. 62. Female venter. 63. Genu, tibiotarsus and solenidia of leg I. 64. Leg IV.

2a except stronger and sparsely barbed; *3a* similar to *3b* and *3c*, barbed, slender; *4a* slender, shorter than *4b*; *4b* as strong as *4c*, barbed, inserted slightly below *4a*. Caudal setae *h2* and *h3* very strong, as strong as dorsal setae, barbed; *h1* small, slender, barbed; *h1* and *h2* approximate at their origins; *h3* distant. Tibiotarsus of leg I as in figure 67, without claw. Solenidion ω_2 very small, peglike; ω_1 large, stout; φ_2 club-shaped; φ_1 slender, straight, slightly longer than φ_2. Seta *d* of femur developed as short, large spine, serrate distally. Tarsus II solenidion ω_1 same form as that of tibiotarsus I. Tibia II and



FIGS. 65–68. *Imparipes longitarsus*, n. sp. 65. Female dorsum. 66. Female venter. 67. Femur, genu, tibiotarsus and solenidia of leg I. 68. Leg IV.

III solenidion φ_1 club-shaped, that on tibia III shorter. Leg IV as in figure 68. Tarsus and pretarsus as long as length of trochanter, genu, femur and tibia together. Tarsus with 6 setae; *t* and *q* short, slender, spinelike; *r* as long as *s*, strong, barbed; *p* stronger and longer than *r* or *s*. Pretarsus about ⅓ as long as tarsus.

Male. Unknown.

Holotype. Female, Rt. 87, Lake Champlain, New York, August 15, 1973, from sphagnum moss collected by M. D. Delfinado.

Paratype. 1 female, with same data as holotype.

Remarks. This species is close to *I.* **similis**, n. sp. but can be readily distinguished by the very small, peglike solenidion ω_2 of tibiotarsus I, and by the serrate seta *d* on femur I. In **similis**, solenidion ω_2 is very long and slender, and seta *d* is simple.

Imparipes **similis**, n. sp.
(Figures 69–71)

Female (*Holotype*). Idiosoma 262 μ long, 223 μ wide, elliptical.

Dorsum. Sensillus capitate, spiculate; prodorsal setae spinelike, *pd1* stronger than *pd2*. Dorsal chaetotaxy and type of setae as in **longitarsus**, n. sp.

Venter. Coxisternal plates well sclerotized, finely punctate. Apodeme 2 developed, curved, joining acetabula of leg II. Apodeme 4 well developed, straight, joining acetabula of leg III. Sternal apodeme (*apsp*) strong, with posterior end faintly joining posterior margin of coexisternal plate. All epimeral setae *1a, 1b, 2a* and *2b* slender, barbed; *2b* not different from other setae; *3a*, *3b* and *3c* similar to *2b* except the former stronger; *4a* slender, sparsely barbed, inserted anterior to *4b; 4b* about as strong as *4c*, barbed. Caudal setae *h1* and *h3* strong, barbed; *h2* small, simple; *h1* and *h2* approximate at their origins; *h3* distant. Tibiotarsus of leg I as in figure 69, without claw. Solenidion ω_2 very long and slender; ω_1 large, tapered distally; φ_2 club-shaped; φ_1 long and slender, shorter than ω_2. Seta *d* of femur as large simple spine. Tarsus II solenidion ω_1 same as that on tibiotarsus I. Tibia II and III solenidion φ_1 club-shaped, about same size. Leg IV as in figure 70. Tarsus and pretarsus long and slender, as long as length of trochanter, genu and femur together. Tarsus with 6 setae; *t* and *q* short, slender, spinelike; *r* as long as *s*, barbed; *p* much stronger than *r* or *s*, barbed. Pretarsus about ½ as long as tarsus.

Male. Unknown.

Holotype. Female (unique), Crescent, Mohawk Valley, October 4, 1973, from rotten log near river collected by M. D. Delfinado.

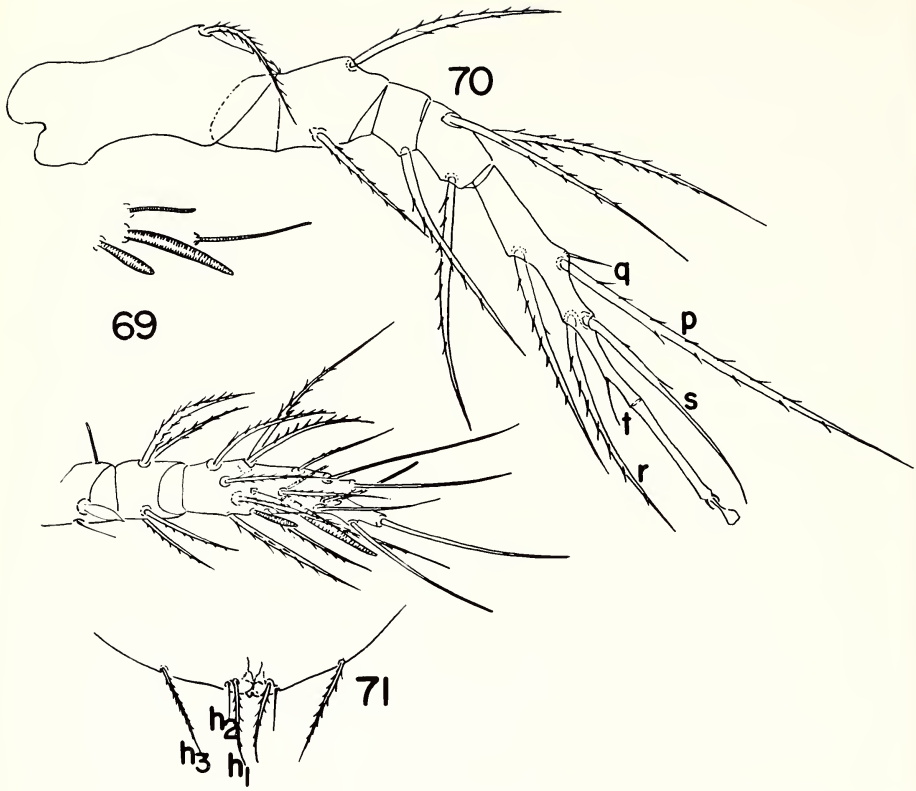
Remarks. *I.* **similis** is distinctive by having very long, slender solenidion ω_2; well developed apodeme 4, and simple caudal setae *h2* and seta *d* of femur I.

Imparipes **tarsalis**, n. sp.
(Figures 72–75)

Female (*Holotype*). Idiosoma 160 μ long, 127 μ wide, ovoid.

Dorsum (fig. 72). Sensillus capitate, spiculate(?); prodorsal setae *pd1* and *pd2* not seen. All dorsal setae simple except *f1*. Setae *c1* as long as *c2*, fairly long, slender; *e2* shorter than *e1*, weak; *d* as long as *e1* and *f2*; *f1* longer than *f2*, fairly strong, barbed at middle.

Venter (fig. 73). Coxisternal plates well sclerotized, posterior plate expanded laterally beyond acetabula of leg IV, finely punctate. Apodeme 2 developed, curved, joining ace-

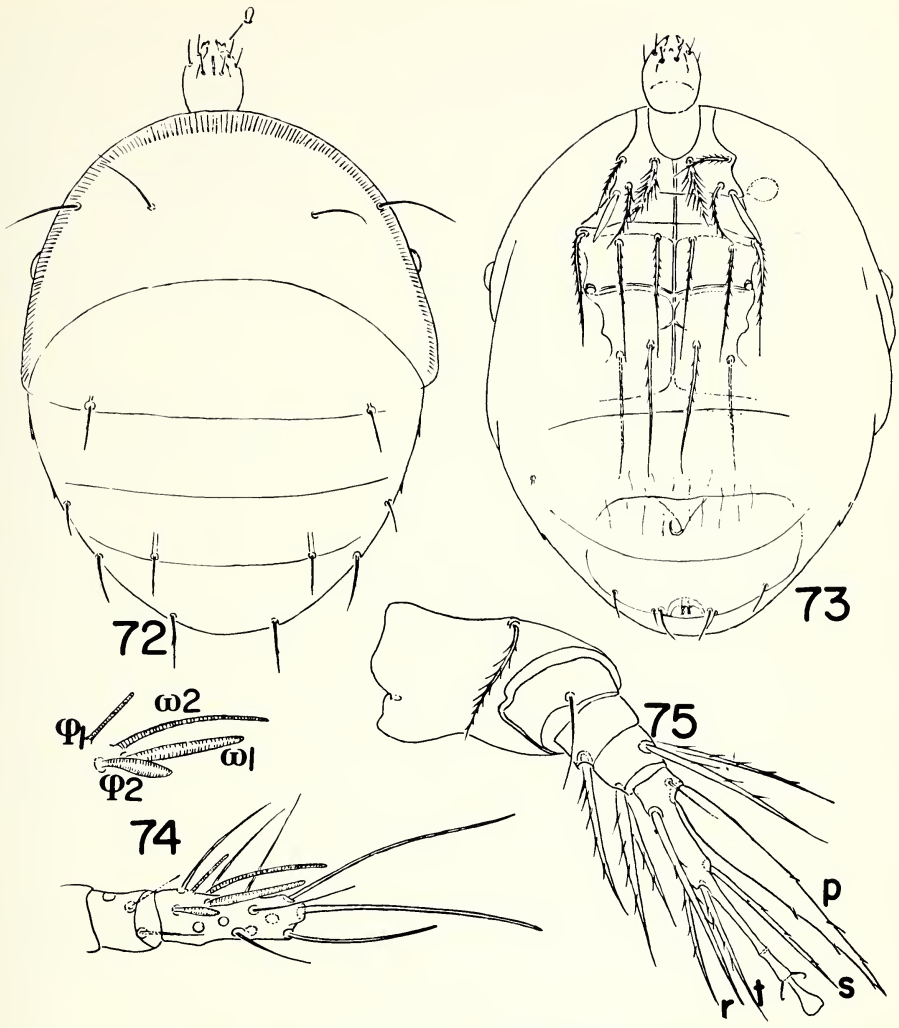


FIGS. 69–71. *Imparipes similis,* n. sp. 69. Femur, genu, tibiotarsus and solenidia of leg I. 70. Leg IV. 71. Caudal setae *h1*, *h2* and *h3*.

tabula of leg II. Apodeme 4 strongly developed, joining acetabula of leg III; a small secondary apodeme present below *ap4*. Sternal apodeme (*apsp*) free. Epimeral setae *1a* large, strongly developed, pectinate; *1b* small, barbed; *2a* similar to *1b* except stronger; *2b* large, daggerlike, smooth; *3a, 3b* and *3c* similar to *4a,* strong, long and barbed; *4b* and *4c* missing. All caudal setae simple; *h2* very short, ½ as long as *h1*; *h3* similar to *h1*, distinct; *h1* and *h2* approximate at their origins. Tibiotarsus of leg I as in figure 74, without claw. Solenidion ω_2 very long, slender, curved; ω_1 stout, straight, shorter than ω_2; φ_1 short, slender, about ½ as long as ω_2; φ_2 club-shaped. Solenidia on tarsus II and tibia II and III not seen due to poor orientation of specimen. Leg IV as in figure 75. Tarsus and pretarsus as long as length of trochanter, genu, and femur. Pretarsus very short, about ⅕ as long as tarsus. Tarsus with 6 setae; seta *t* same type as *r* and *s*, not spinelike; seta *p* immensely developed, lanceolate, serrate distally; *q* short, hairlike.

Male. Unknown.

Holotype. Female (unique), Sunken Meadow State Park, Smithtown Bay, Long Island, New York, June 25, 1973, from a tree hole debris collected by M. D. Delfinado and M. J. Abbatiello.

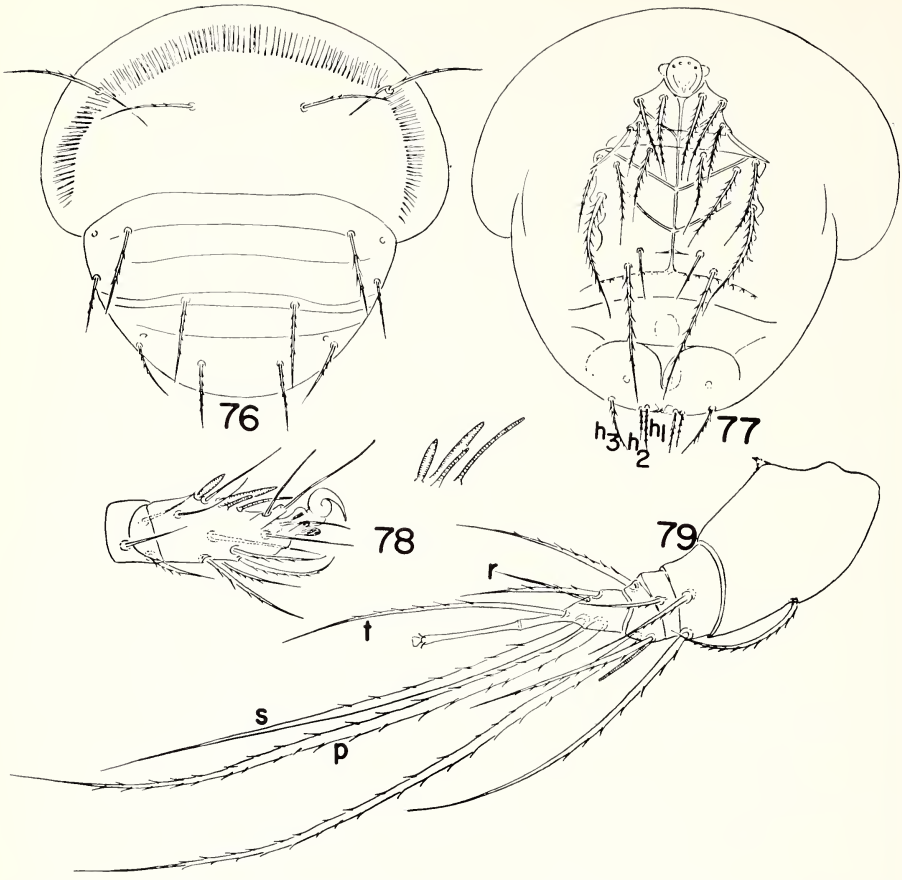


Figs. 72–75. *Imparipes tarsalis*, n. sp. 72. Female dorsum. 73. Female venter. 74. Genu, tibiotarsus and solenidia of leg I. 75. Leg IV.

Remarks. This species falls into the group that has no claw on leg I. *I.* **tarsalis**, n. sp. is distinguished from the other species in having the seta *p* immensely developed and the epimeral setae *2b* large and daggerlike; also it has the pretarsus very short and seta *t* the same type as *r* or *s*.

Imparipes degenerans italicus Berlese
(Figures 76–79, 84)

Imparipes degenerans var. *italicus* Berlese, 1904, Redia 2: 10. Rack, 1966, Adh. Verh. Naturwiss, Ver. Hamb. 10: 100, figs. 2–4.



FIGS. 76–79. *Imparipes degenerans italicus* Berlese. 76. Female dorsum. 77. Female venter. 78. Genu, tibiotarsus and solenidia of leg I. 79. Leg IV.

Female. Idiosoma 243 μ long, 274 μ wide, obovate, much broader anteriorly.

Dorsum (fig. 76). Sensillus capitate, spiculate; prodorsal setae *pd1* very large and strong, as long as sensillus; *pd2* about ½ as long as *pd1*. Setae *c1* and *c2* slender, longer than posterior dorsal setae, barbed; *d* as long as *e1*, *e2*, *f1* and *f2*, strong, barbed.

Venter (fig. 77). Coxisternal plates well sclerotized, finely punctate. All apodemes strongly developed. Apodemes 2 and 4 complete. Sternal apodeme (*apsp*) joined posteriorly to margin of coxisternal plate. Epimeral setae *1a* stronger than *1b* and *2a*, barbed; *2b* dagger-like, smooth; *3b* longer than *3a* and *3c*, barbed; *4a* short, about ½ as long as and inserted anterior to *4b*, sparsely barbed or may be simple; *4c* as long as *4b* but stronger. Caudal setae (fig. 84) *h1*, *h2* and *h3* sparsely barbed; *h1* shorter than *h2*; *h3* longer and stronger *h2* distant. Tibiotarsus of leg I as in figure 78, with a claw. Solenidion ω_2 long and slender; ω_1 stout, tapered distally, shorter than ω_2; φ_2 short, slender, about as long as φ_1; φ_1 stout, club-shaped. Tarsus II solenidion ω_1 same form as that on tibiotarsus I

except slightly smaller. Tibia II and II solenidion φ_1 slender, characteristically club-shaped, that on tibia III much longer, about as long as length of tibia. Leg IV as in figure 79, with a small solenidion on tibia. Tarsus and pretarsus about as long as length of trochanter and genu together. Pretarsus as long as tarsus. Tarsus with 5 setae; seta *r* weak, short and simple.

Specimens examined. 5 females, near MacArthur Airport, Islip, Long Island, New York, July 16, 1973, from pine debris collected by M. D. Delfinado and M. J. Abbatiello.

Remarks. This species appears to be fairly common in Europe. It differs from the typical *degenerans* Berlese by the type and size of seta *t* on tarsus IV; this seta is much thinner and shorter in the type form as shown by Berlese (1904b) and Rack (1965).

Imparipes degenerans nearcticus, n. subsp.
(Figures 80–83)

Female (*Holotype*). Idiosoma 325 μ long, 268 μ wide, obovate.

Dorsum (fig. 80). Sensillus (fig. 82) capitate, spiculate; prodorsal setae *pd1* stout; *pl2* small, about ½ as long as *pd1*. Type of dorsal setae as in *degenerans italicus* Berlese except: *d, e1, e2, f1* and *f2* slightly longer, and *c1* shorter than *c2*.

Venter (fig. 81). Essentially as in *d. italicus*. Setae *4a* simple (or with 1–2 fine barbs in paratype specimens). Caudal setae (fig. 83) *h1, h2* and *h3* long and well differentiated from other setae, short plumose. Legs I and IV as in *d. italicus*.

Male. Unknown.

Holotype. Female, pine grove on Rt. 9W, New Baltimore, New York, July 16, 1974, from pine debris collected by M. D. Delfinado.

Paratypes. 14 females, with same data as holotype; 1 female, Rt. 87, 36 mi. north of New York City, July 22, 1973, from litter; 2 females, Palisades Park, New Jersey, from oak litter; 10 females, Stafford, Virginia, July 3, 1973, from mixed forest litter collected by E. W. Baker. The New York and New Jersey material were collected by M. D. Delfinado.

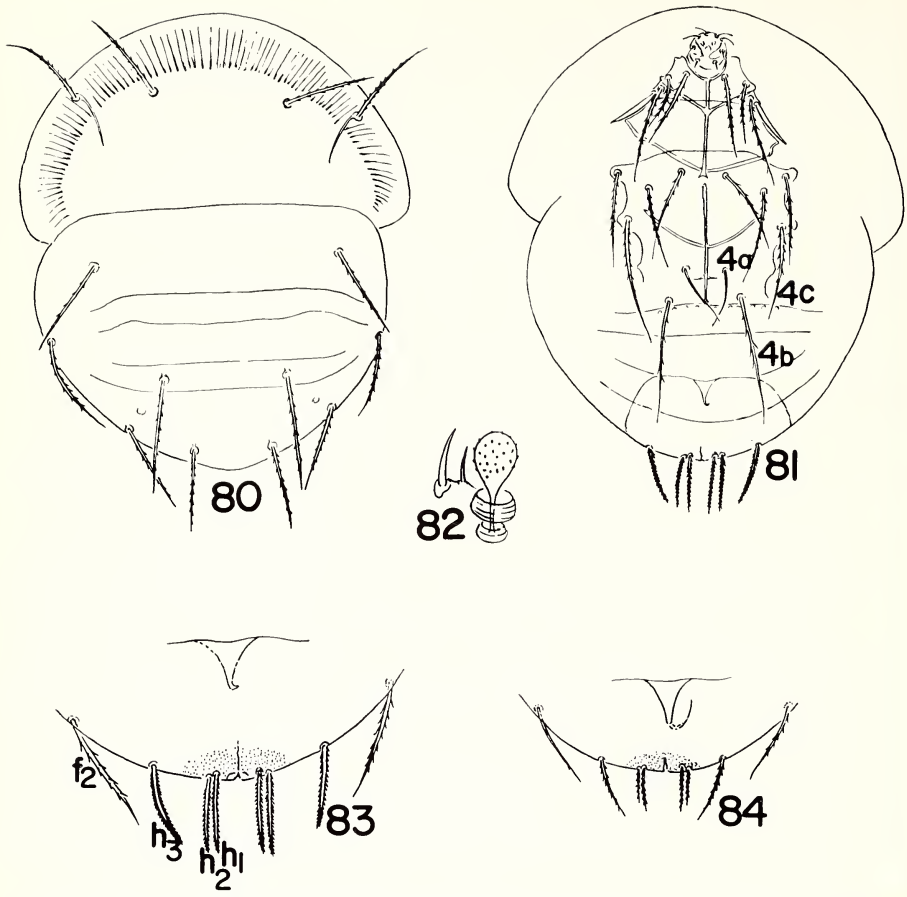
Remarks. This subspecies primarily differs from the type form and *d. italicus* Berlese by the characteristic development of the caudal setae (fig. 83); in the type form and *d. italicus*, the corresponding setae are unequal and sparsely barbed.

Imparipes **insulanus**, n. sp.
(Figures 85–88)

Female (*Holotype*). Idiosoma 223 μ long, 217 μ wide, elliptical.

Dorsum (fig. 85). Sensillus capitate, spiculate; predorsal setae *pd1* and *pd2* spinelike, hardly discernible. Setae *c1* and *c2* shorter than most posterior setae; *d*, *e1* and *e2* shorter than *f1* and *f2*; all dorsal setae strong and barbed.

Venter (fig. 86). Coxisternal plates well sclerotized, finely punctate. All apodemes well developed, strong. Apodeme 2 complete, straight, joining acetabula of leg II. Apodeme 4 with ends faintly connected to acetabula of leg III. Posterior sternal apodeme (*apsp*) free. Epimeral setae *1a* stronger than *1b* and *2a*, barbed; *2b* not much differentiated from others, as strong as *1a* except shorter; *3a* slender, simple, inserted anterior to *3b*; *3b* lanceolate, straddling on apodeme 4, smooth; *3c* slender, barbed; *4a* similar to *3b*, lanceolate;

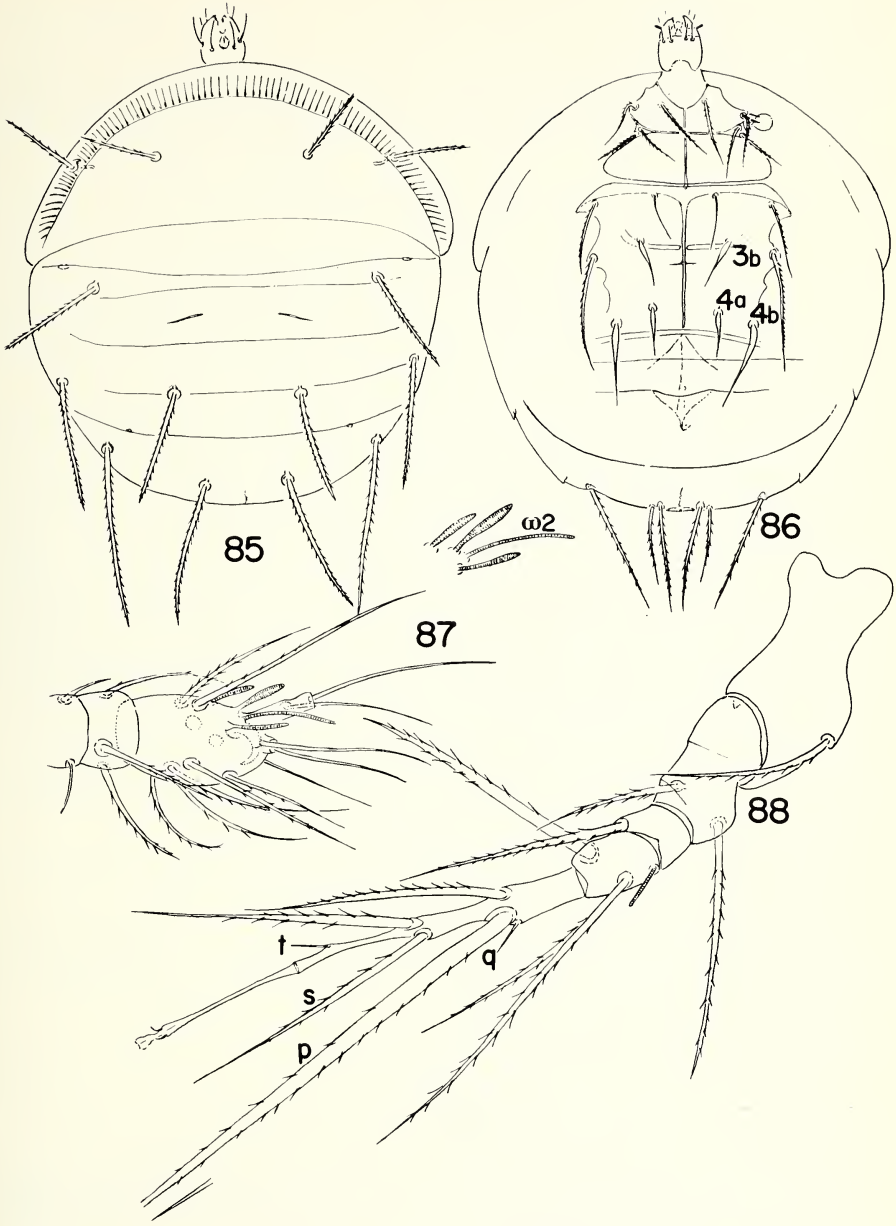


FIGS. 80–83. *Imparipes degenerans nearcticus*, n. subsp. 80. Female dorsum. 81. Female venter. 82. Sensillus and prodorsal setae *pd1* and *pd2*. 83. Caudal setae *h1*, *h2* and *h3*.
FIG. 84. Caudal setae *h1*, *h2* and *h3* of *Imparipes d. italicus* Berlese.

4b similar to *4a* except much longer; *4c* barbed, longer than *3c*. All caudal setae barbed and strong; *h1* longer than *h2*; *h3* longer than *h1*, distant. Tibiotarsus I as in figure 87, without a claw. Solenidion ω_2 very long, slender; ω_1 large, club-shaped, shorter than ω_2; φ_2 slender, almost straight; φ_1 club-shaped, about as long as φ_2. Leg IV as in figure 88, with a small solenidion on tibia. Tarsus and pretarsus as long as length of trochanter, genu, femur and tibia together. Pretarsus ½ as long as tarsus. Tarsus with 6 setae; setae *t* and *q* very small, as short, weak spines; *r* and *s* equal in length, hardly reaching tip of empodium.

Male. Unknown.

Holotype. Female, Robert Moses State Park, Great South Bay, Long Island, New York, June 14, 1973, from mixed plant litter collected by M. D. Delfinado and M. J. Abbatiello.



Figs. 85–88. *Imparipes insulanus*, n. sp. 85. Female dorsum. 86. Female venter. 87. Genu, tibiotarsus and solenidia of leg I. 88. Leg IV.

Paratype. 4 females, with same data as holotype. (Note. 2 paratype specimens are smaller than holotype, measuring 191 μ long, 185 μ wide.)

Remarks. *I.* **insulanus**, n. sp. is remarkably close to *I. minor* Karafiat from Germany. Both species have the same type of setae and pattern on the venter of idiosoma and leg IV. *I.* **insulanus**, however, is most easily distinguished in having all dorsal and caudal setae barbed.

Imparipes **humilis**, n. sp.
(Figures 89–93)

Female (*Holotype*). Idiosoma 160 μ long, 160 μ wide, elliptical.

Dorsum (fig. 90). Sensillus capitate, spiculate; prodorsal setae spinelike, *pd1* longer than *pd2*. All dorsal setae long and strong, barbed; *c1* and *c2* as long as *e2*, *f1* and *f2*; *d* longest of dorsal setae, more than ½ length of idiosoma; *e1* longer than *e2*, *f1* and *f2*.

Venter (fig. 89). Coxisternal plates well sclerotized, finely punctate. Apodemes well developed, strong. Apodeme 2 developed, joining acetabula of leg II. Apodeme 4 short, free, not joining acetabula of leg III. Sternal apodeme (*apsp*) joining posteriorly to acetabula of leg IV. Epimeral setae *1a*, *1b* and *2a* slender, barbed; *2b* large, daggerlike, barbed; *3a* shorter than *3b* and *3c*, slender, barbed; *4a* shorter than, and inserted anterior to *4b*; *4b* similar to *4c*, strong. Caudal setae *h1* as strong as *h3*, barbed; *h1* small, simple. Tibiotarsus of leg I as in figure 92, with a claw. Solenidion ω_2 shorter than ω_1, slightly swollen; ω_1, club-shaped; φ_2 long, slender, rodlike; φ_1, small, slender, capitate. Tarsus II and tibia III solenidia not seen due to poor orientation of specimen. Leg IV as in figure 93, with a small solenidion on tibia. Tarsus and pretarsus as long as length of trochanter, genu, femur and tibia together. Pretarsus as long as tarsus. Tarsus with 5 setae; *r* very short, simple; *t* and *s* not reaching beyond empodium.

Male. Unknown.

Holotype. Female, Colonie, 2 mi. west of airport, Albany County, New York, April 10, 1973, from forest humus collected by M. D. Delfinado.

Paratypes. 2 females, with same data as holotype (1 paratype measuring 204 μ long, 166 μ wide).

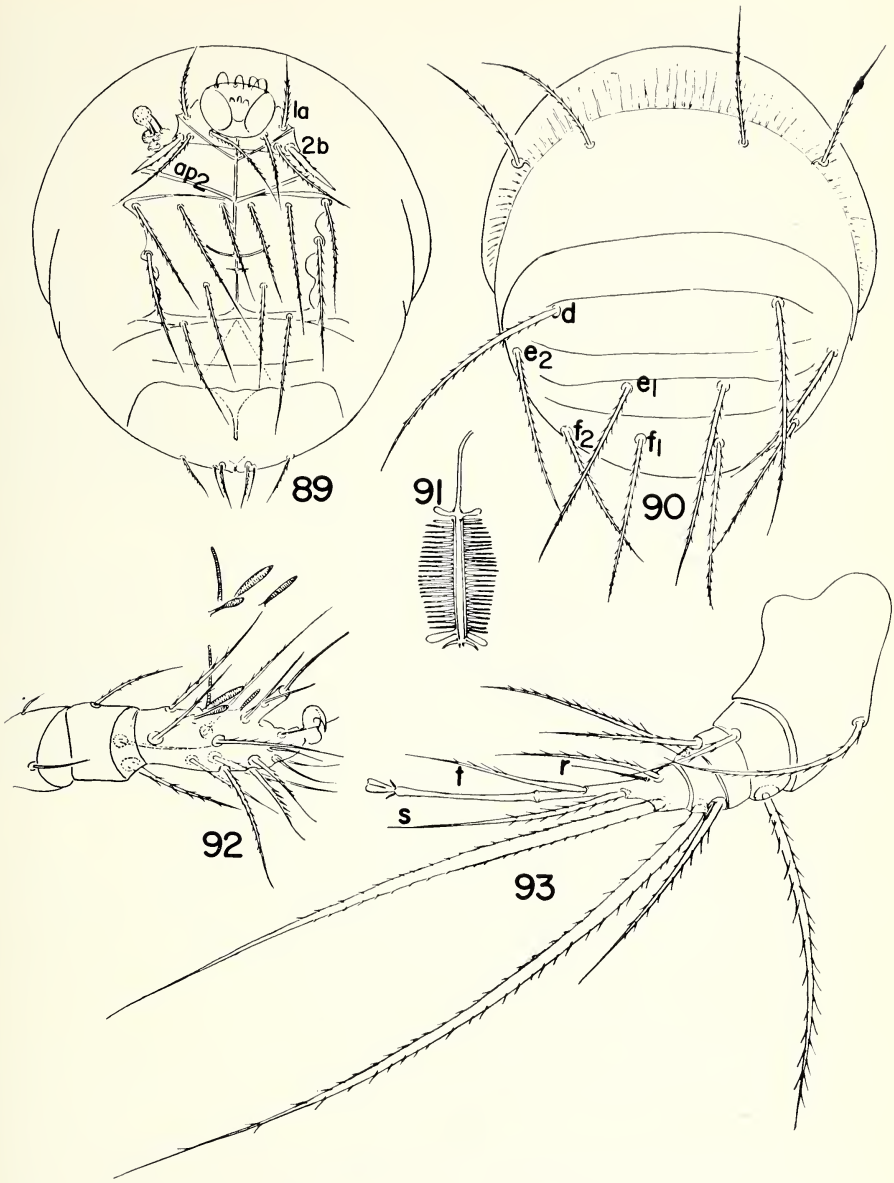
Remarks. This species is quite distinctive in having only 5 setae on tarsus IV (seta *q* missing), and barbed daggerlike epimeral setae *2b*; also solenidion ω_2 on tibiotarsus I is well differentiated from that of other species.

Imparipes **parapicola**, n. sp.
(Figures 94–97)

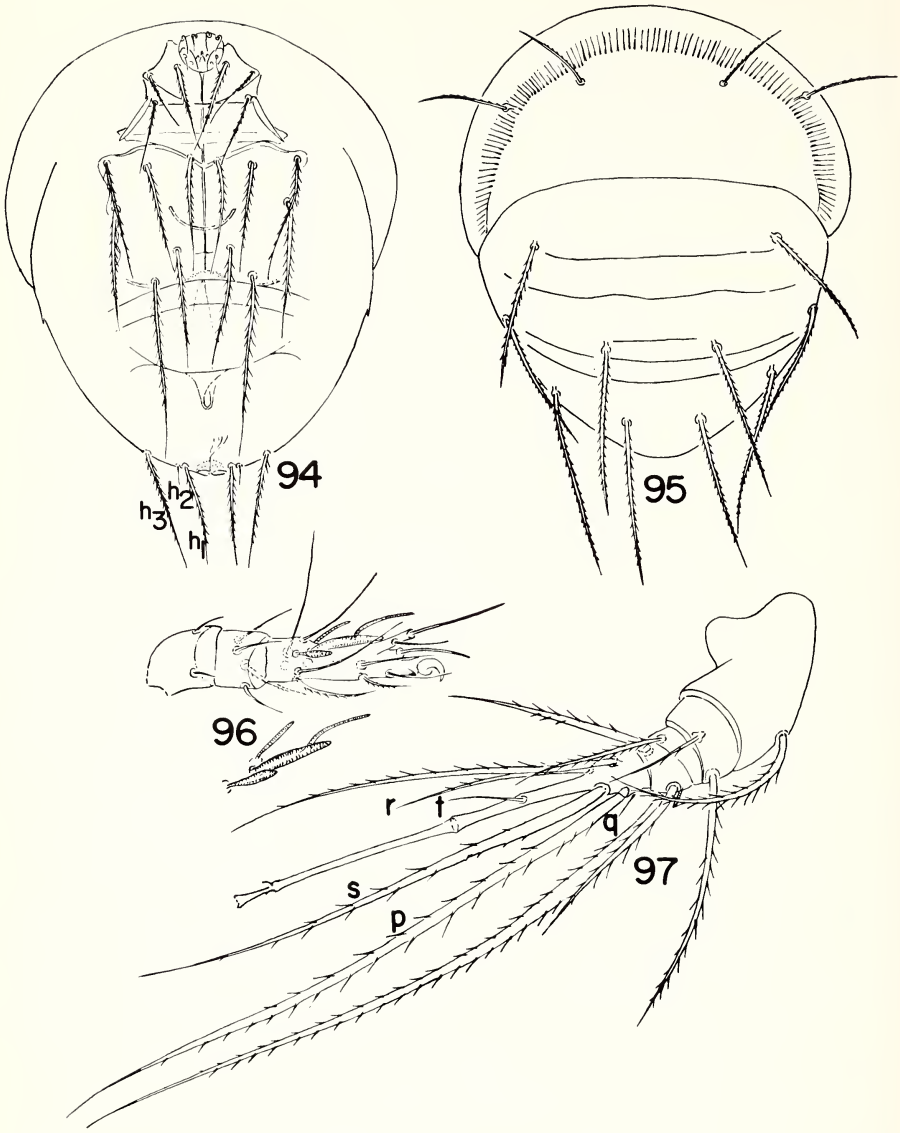
Female (*Holotype*). Idiosoma 191 μ long, 159 μ wide, obovate.

Dorsum (fig. 94). Sensillus capitate, spiculate; prodorsal setae *pd1* and *pd2* very small. All dorsal setae robust and barbed; *c1* as long as *c2*, shorter and less robust than posterior setae; *d*, *e1*, *e2*, *f1* and *f2* equally long.

Venter (fig. 95). Coxisternal plates well developed, punctate. Apodemes strong. Apodeme 2 complete. Apodeme 4 short, free, not joining acetabula of leg III; a small secondary apodeme present below *ap4*. Sternal apodeme (*apsp*) posteriorly faintly connected to acetabula of leg IV. All epimeral setae barbed except *2b*; *1a* stronger than *1b* and *2a*;



Figs. 89–93. *Imparipes humilis*, n. sp. 89. Female venter. 90. Female dorsum. 91. Pharyngeal armature(?). 92. Genu, tibiotarsus and solenidia of leg I. 93. Leg IV.



FIGS. 94–97. *Imparipes parapicola*, n. sp. 94. Female venter. 95. Female dorsum. 96. Femur, genu, tibiotarsus and solenidia of leg I. 97. Leg IV.

2b saberlike, smooth; *3a* similar to *3b* and *3c*, strong, barbed; *4a* shorter than *4b* and *4c*, inserted above *4b*; *4b* long, reaching posterior margin of hysterosoma. Caudal setae *h1* and *h3* strong, long and barbed, same thickness; *h2* very small, simple. Tibiotarsus of leg I as in figure 96, with a claw. Solenidion ω_2 long and slender; ω_1 large, tapered distally; φ_2 same form as ω_2 except shorter; φ_1 small, club-shaped. Tarsus II solenidion

ω_1 same form as that of tibiotarsus I except smaller. Tibia II and III solenidion φ_1 club-shaped, about same size. Leg IV as in figure 97, with a small solenidion on tibia. Tarsus and pretarsus much longer than length of trochanter, genu, femur and tibia together. Pretarsus as long as tarsus. Tarsus with 6 setae; seta *q* very small, simple ½ as long as *t*; *r* short, simple, reaching basal ⅓ of pretarsus.

Male. Unknown.

Holotype. Female, Sunken Meadow State Park, Smithtown Bay, Long Island, New York, June 26, 1973, from tree hole debris collected by M. D. Delfinado and M. J. Abbatiello.

Paratypes. 6 females, with same data as holotype; 2 females, Cross Island Parkway, Little Neck Bay, Long Island, New York, from plant litter on roadside; 1 female, Sacandaga, Adirondack Mts., New York, September 12, 1973, from forest humus. All collected by M. D. Delfinado.

Remarks. This species differs from *I. apicola* (Banks) from Ontario in having well differentiated solenidia ω_1 and φ_2 (fig. 96), and thickly barbed epimeral setae. In *apicola*, the corresponding solenidia are of the same size and form, and the epimeral setae are sparsely barbed.

Imparipes apicola (Banks), new combination

Disparipes apicola Banks, 1914, Jour. Ent. & Zool. 6: 61.

Scutacarus apicola, Mahunka, 1965, Acta Zool. Acad. Sci. Hung. 11: 383.

Mahunka (1965) listed *apicola* in combination with *Scutacarus* as *species inquirenda*. We have examined the type of *apicola*; it distinctly belongs to the genus *Imparipes*. At present, we have no specimens of this species from New York.

Imparipes obsoletus Rack
(Figures 98–102)

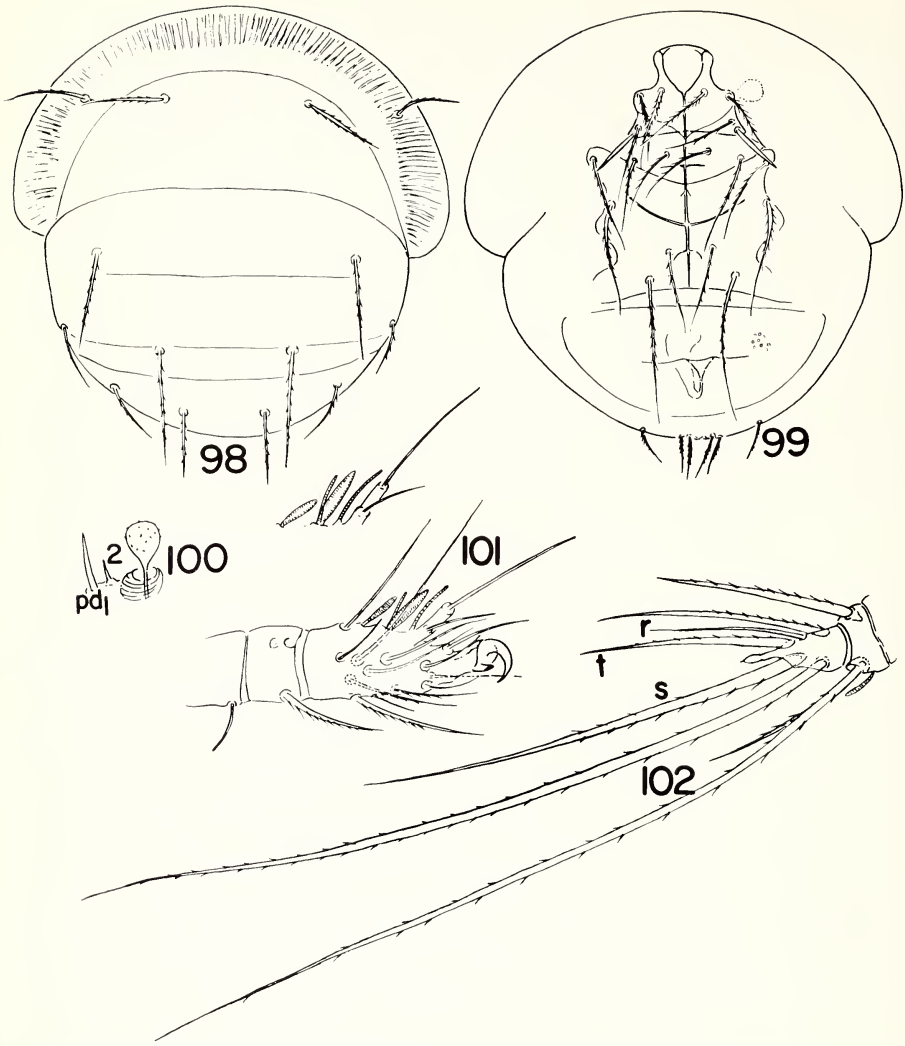
Imparipes (*I.*) *obsoletus* Rack, 1965, Abh. Verh. Naturwiss. Ver. Hamb. 10: 99 (n. n. for *Imparipes hystricinus degenerans* of Paoli, 1911, misidentification, not Berlese, 1904).

Imparipes (*I.*) *hystricinus degenerans* of Paoli, 1911, Redia 7: 259, figs. 57, 58, 60.

Female. Idiosoma 223 μ long, 223 μ wide, elliptical.

Dorsum (fig. 98). Sensillus capitate, spiculate (fig. 100); prodorsal setae spinelike, *pd1* large, strong, *pd2* very small. All dorsal setae barbed; *c1* as long as *c2*, shorter than *d* and *e1*, strong; *d* as long as *e1*, longest and strongest of dorsal setae; *e2* as long as *f1* and *f2*, short.

Venter (fig. 99). Coxisternal plates well sclerotized, finely punctate. Apodemes 2 and 4 complete, connected to acetabula of legs II and III respectively; a small secondary apodeme present below *ap4*. Sternal apodeme with posterior end free. All epimeral setae barbed except *2b*; *1a* similar to *2a*, stronger than *1b*; *2b* daggerlike, smooth; *3a* shorter than *3b* and *3c*, slender; *4a* shorter than and inserted anterior to *4b*; *4b* long, reaching posterior margin of hysterosoma. Caudal setae *h1* and *h2* as long as *h3*, finely barbed; *h1* and *h2* approximate at their origins; *h3* distant. Tibiotarsus of leg I as in figure 101, with a claw. Solenidion ω_2 long and slender, about as long ω_1; ω_1 stout, tapered



FIGS. 98–102. *Imparipes obsoletus* Rack. 98. Female dorsum. 99. Female venter. 100. Sensillus and prodorsal setae *pd1* and *pd2*. 101. Genu, tibiotarsus and solenidia of leg I. 102. Leg IV.

distally; φ_2 slender, about as long as φ_1; φ_1 club-shaped. Tarsus II solenidion ω_1 as large as that on tibiotarsus I. Tibia II and III solenidion φ_1 long, paddle-shaped, same size. Tibia and tarsus of leg IV as in figure 102, without claws and empodium; with a club-shaped solenidion on tibia. Pretarsus very short, bearing a minute spine at tip. Tarsus and pretarsus shorter than length of trochanter. Tarsus with 5 setae; seta *r* simple, shorter than *t*.

Male. Unknown.

Material examined. 2 females, Farmingdale, Long Island, New York, June 30, 1973, from a bird nest; 5 females, near Bolton Landing, Adirondack Mts., New York, August 18, 1973, from soil near base of a tree; 2 females, Oceanside Marine Study Area, Nassau County, Long Island, New York, June 18, 1973, from debris; 1 female, Palisades, New Jersey, June 24, 1973, from oak leaf litter. All collected by M. D. Delfinado.

Remarks. This mite is probably the species reported from Florida as *Imparipes* (*I.*) *hystricinus degenerans* Berlese by Paoli (1911:259). At first glance it appears typical of genus *Imparipes*. The absence of claws and empodium on leg IV is a striking characteristic of *I. obsoletus*.

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CONTENTS

On the Oviposition Habits of 13-Year Versus 17-Year Periodical Cicadas of the Same Species

MONTE LLOYD
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Abstract: Three species of periodical cicadas occur intermixed in roadside vegetation, ovipositing at eye level within easy reach. By collecting these, and noting the plant species on which each individual is ovipositing, one can assess the oviposition preferences of a given species relative to those of other species. The data thus far indicate that both 13-year and 17-year counterparts of *Magicicada septendecula* prefer hickory more than do the other two species, also that both counterparts of *M. septendecim* prefer (more than does *M. cassini*) those tree species that are capable of becoming canopy dominants in mature upland forest.

There are three perfectly synchronized species of periodical cicadas that coexist over most of their range in Eastern North America: *Magicicada septendecim*, *M. cassini*, and *M. septendecula*. They have a 17-year life cycle in the northern part of their range and a 13-year life cycle in the southern part. Alexander and Moore (1962) applied different species names to 13-year cicadas, even though they could find no differences in song, and no differences in morphology between the 13-year and 17-year counterparts for any of the three species. A color difference was claimed between 13- and 17-year *M. septendecim*, but this has never been substantiated or documented quantitatively. In this paper and others to follow, we show that one cannot find any ecological differences between 13-year and 17-year counterparts either. Accordingly, rather than call indistinguishable entities by different species names, we prefer to use the original (17-year) names throughout.

Dybas and Lloyd (1962, 1974, in prep.) have studied the habitat relations of 17-year cicadas in several broods over a period of 18 years. In mature,

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closed-canopy forests, *M. cassini* occurs mainly on the floodplain and *M. septendecim* occurs manily on the uplands. The same pattern is found in 13-year cicadas (Lloyd and Dybas, in prep.). *Magicicada septendecula* is usually by far the rarest of the three species. It sometimes occurs in upland patches interspersed with *M. septendecim*, but comes into greatest prominence in forest-prairie ecotone situations, i.e., large open-grown trees (especially hickories) with a grassy understory. We infer that this was the general picture partial separation of periodical cicada species in adjacent habitats throughout the deciduous forests of eastern North America prior to European settlement.

Today, vast areas of former forests are transformed into farmlands and suburban gardens. Woody vegetation persists, e.g., along streams and roadsides, on hilltops or isolated farm plots, on abandoned farms, in public parks, in suburbs. Much of this is second growth, dominated by successional species. Nevertheless, periodical cicadas thrive in this kind of vegetation. Females seem to prefer ovipositing in sunlit vegetation: isolated small trees, open second growth, along forest edges, along roadsides. In such vegetation, the twigs are loaded with cicada eggs to an astonishing degree and the three species often become thoroughly intermixed (White, in prep.). As Alexander and Moore (1962) put it, "—sympatry is about as complete as it possibly could be."

One has all three cicada species ovipositing within easy reach, in the same vegetation, at the same time. This provides an excellent opportunity to investigate oviposition preferences, which may have evolved in former centuries when populations were partially separated in adjacent woodland habitats having different plant species. One simply collects, by hand or by net, females seen in the act of oviposition, and records the plant species on which each is ovipositing. The data fit into a conventional chi-square contingency table analysis. Dybas and Lloyd (1974, Figs 18, 19, Table 11) did this during an emergence of 17-year Brood IV in 1964 at Tall Oaks, near Linwood, Kansas. They found 98/102 *septendecula* females ovipositing in hickory, versus 37/60 for *cassini*, versus 80/286 for *septendecim*, which clearly demonstrates a much stronger preference for hickory in *septendecula* than in *cassini* and *septendecim* (lumping the latter two, Fisher exact test, $P < 10^{-30}$). This result was anticipated from earlier studies of microdistribution (Dybas and Lloyd 1974).

RESULTS AND DISCUSSION

In field studies of other broods, we have often tried to repeat this kind of collection of ovipositing females, but found it difficult because *septendecula* is usually a rare species (Alexander and Moore 1962, Dybas and Lloyd 1974). Table 1 presents the only two cases we have where enough *septendecula* were caught to subject the data to statistical analysis.

The data from 1972 at Ramsey Lake State Park, Illinois, are especially interesting because these are 13-year cicadas (Brood XIX) and hickories are

TABLE 1. Numbers of periodical cicadas laying their eggs in various host species: samples from two different areas and times.

	Ramsey Lake			Eden Shale		
	M. septen-decim	*M. cassini*	*M. septen-decula*	*M. septen-decim*	*M. cassini*	*M. septen-decula*
Carya spp. (twigs)	47	11	6	7	21	4
Carya spp. (petioles)	–	3	4	–	2	1
Quercus alba	31	3	–	7	10	–
Quercus stellata	1	–	–	–	–	–
Quercus velutina	20	5	–	8	19	1
Quercus muehlenbergii	–	–	–	4	3	–
Acer saccharum	6	1	–	–	–	–
Ulmus americana	11*	15	1	–	1	–
Ulmus rubra	9	7	–	2	3	–
Fraxinus americana	12	–	2	3	13	–
Cercis canadensis	1	4	–	5	47	5
Juniperus virginiana	1	2	–	–	8	–
Cornus drummondii	6	23	–	–	–	–
Cornus florida	–	–	–	–	1	–
Robinia pseudo-acacia	4	12	–	–	–	–
Gleditsia triacanthos	–	–	–	–	2	–
Crataegus mollis	–	–	–	–	8	–
Crataegus crus-galli	–	–	–	–	1	–
Crataegus pruinosa	19	11	–	–	–	–
Diospyros virginiana	1	–	–	–	–	–
Sassafras albidum	–	–	–	–	5	–
Salix nigra	2	–	–	–	–	–
Prunus serotina	8	15	–	–	–	–
Prunus americana	–	–	–	–	3	–
Totals	179	112	13	36	147	11

Note—At Ramsey Lake State Park, Illinois (13-year Brood XIX, 13–14 June, 1972), the hickories were *Carya laciniosa*, *C. glabra*, and possibly *C. ovalis*, not distinguished. At Eden Shale Farm, near Sweet Owen, Kentucky (17-year Brood XIV, 5–20 June, 1974), the hickories were *Carya ovata* and *C. glabra*, not distinguished.

* One of these may have been in *Ulmus rubra*.

abundant at Ramsey Lake. We anticipate that 13-year *M. septendecula* will prefer to oviposit in hickories, just as 17-year ones do. The prediction is confirmed: 10/13 *septendecula* were caught ovipositing in hickories, versus 61/291 for *cassini* and *septendecim* combined. By Fisher exact test, $P = .00004$.

Also in Table 1 we give data from 1974 at Eden Shale Farm near Sweet Owen, Kentucky (Brood XIV), where hickories were not so abundant as at Ramsey Lake. These data confirm once again the expected preference of 17-year *septendecula* for hickories: 5/11 for *septendecula* versus 30/183 for the other two species. By Fisher exact test, $P = .03$. In our experience thus far, the preference of *septendecula* for hickory is stronger, the more the vegetation itself is dominated by hickory.

Rationale of applying contingency analysis to ovipositing cicadas: It is important to understand what is being tested by the contingency table chi-square

(or its equivalent for 2×2 tables, the Fisher exact test), which assumptions are necessary, and which are not. The contingency table does not measure oviposition preference in any absolute sense. To do that, one obviously needs to measure all the twigs of suitable size (3 mm to 11 mm, White 1973) available in an area, and how much of what was available was used by each cicada species. This has been done in another part of Illinois for 13-year Brood XIX in 1972; a full report is in manuscript (White, in prep.). White finds that none of the cicada species oviposits indiscriminantly. Despite the wide variety of plant species acceptable, each cicada species has its own distinct set of preferences.

Based only on a collection of ovipositing females, the contingency table assesses a given cicada species' preferences *relative* to the preferences of other species. Without measuring either, we can still ask whether they were the same, because we know that the availability of the various plant species to the various cicada species was the same. The contingency table is a conditional test. We use it to test the null hypothesis that *septendecula* does not prefer, any more than do the other two species, to oviposit in hickory. We found 10 of 13 *septendecula* females ovipositing in hickory at Ramsey Lake, compared with 61 of 291 females of the other two cicada species. We ask, "What are the chances, under the null hypothesis, of 10 or more *septendecula* ovipositing in hickory?" The answer is $P = .00004$, so we reject the null hypothesis that *septendecula* has no preference for hickory, even though we still have not measured how great that preference is.

Our conclusions obviously apply only to the area that was sampled. We do not know what is happening out of reach in the forest canopy, but this does not affect the validity of our test of the null hypothesis for cicadas at eye level. If we could devise a method to collect ovipositing females in the canopy, we would have a different contingency table with different marginal totals, but test the same null hypothesis. The fact that both cicada and plant species might have different proportions in the canopy versus at eye level makes no difference.

Obviously one must make an honest effort to collect every ovipositing female one sees at eye level, irrespective of what species it is or what plant it is on. If we were deliberately to avoid collecting some individuals of *septendecim* and *cassini* ovipositing in hickory, but assiduously collect all the *septendecula* we saw on hickory, then of course that would invalidate the test. However, non-interactive biases do not do so. *Magicicada septendecula* and *M. cassini* are relatively skittish and harder to catch than *M. septendecim*; we always miss some. *Crataegus* is full of thorns, which makes it harder to collect (by hand or net) all females ovipositing in it. We probably do not catch as high a proportion of females ovipositing in *Crataegus* as there really are. Both kinds of bias affect the marginal totals, but not the validity of the test.

There is a potentially important source of error that is not obvious and is difficult to evaluate. We have what appears to be a homogeneous mixture of three cicada species, but we can't really be sure about it. Males are attracted to the singing of conspecific males (Alexander and Moore 1958) and conspecific females might also be attracted to each other. If so, then they are not moving independently. Such behavior would create a patchy pattern of microdistribution, perhaps unrelated to the patchy pattern of the vegetation. Superimposition of the two would produce a spurious association between cicada species and plant species—an association that would change in different times and places. In other words, a "group" of *septendecula* females might just happen to coincide with a patch of hickory for reasons of historical accident having nothing to do with the properties of hickory, but this would not happen consistently again and again. The statistical contingency test relys absolutely on the unproved assumption that female cicadas choose oviposition sites independently. Perhaps females really do move independently; certainly they move around actively. Nevertheless, to be convincing, this association with hickory (or any other) needs to be demonstrated repeatedly at different times in different places-no matter how great the significance of chi-square for any one time and place. Behavioral studies on female cicadas also need to be conducted.

We hope that further collections of ovipositing females will be made in the next few years.[1] *Magicicada septendecula* is well represented in 13-year Brood XXIII emerging in 1976 in the Mississippi River Valley from southern Illinois to Louisiana. Alexander and Moore (1962) show it also in 17-year Broods XVII, I, and II, emerging in the Appalachians and Eastern Seabord in 1977, 1978, and 1979. Making a large collection of ovipositing females is not difficult, since they do not readily flee when approached. It is merely a matter of being in the right place at the right time.

Analysis for M. cassini versus M. septendecim: So that our conclusions will be statistically independent of those for *M. septendecula*, we omit that species in what follows. From the work of Dybas and Lloyd (1962, 1974), one can anticipate that *septendecim* should prefer upland forest species more than *cassini*, which should prefer floodplain species more than *septendecim*. If the collection site contains an adequate representation of plant species, the hypothesis should be testable. Notice in Table 1 that no floodplain species of hickory, oak, or maple are represented—all are upland species. If we consider ashes and elms as floodplain species, then the hosts can be grouped as follows: (hickories, oaks, and sugar maple) vs (ashes and elms) vs (others). By our *a priori*

[1] If any readers wish to make their own collections of ovipositing females, separated according to plants being used, the authors will be delighted to help with identifying the cicadas. We will also be pleased to have your pressed plant specimens competently identified.

hypothesis, neither cicada species should show any relative preference for "others".

We begin with the Eden Shale data for 17-year cicadas. Using the above lumped categories for host species (listed in the same order), the expected numbers of ovipositing *M. septendecim* females, on the null hypothesis of no preference, were (16) vs (4) vs (16)—rounded to the nearest integer. Observed were (26) vs (5) vs (5). Conversely, for *M. cassini*, we expect (65) vs (17) vs (64) and observe (55) vs (17) vs (80). From this 2×3 contingency table, chi-square is 17.2, $P < .0002$. The deviations from expectation are statistically significant, but somewhat contrary to the predicted pattern. *M. septendecim* shows a relative preference for upland species as predicted, but *cassini,* instead of showing a relative preference for floodplain species, is relatively prone to oviposit in "others". These "others" are mainly shade-intolerant, successional, second-growth species (mainly redbud, red cedar, hawthorn, and sassafras) that will readily invade cleared land anywhere, whether in upland or floodplain topographic situations. None of these species are dominant canopy trees in virgin forests; all have doubtless increased greatly in abundance following European settlement.

On reflection, this pattern of *cassini* ovipositing in "others" is understandable and might have been anticipated. Except for forested mountainous regions in the Eastern United States, vast areas of original forest have been cleared for farmland (see Dybas and Lloyd 1974 for an account of Ohio). Floodplain forests have been cleared sooner and more thoroughly than upland forests because alluvial soil is generally more fertile and easier to farm than is the adjacent upland soil. In Oklahoma, owing to suppression of fires, upland forests have actually increased since European settlement—but not floodplain forests (Rice and Penfound 1959). For both *M. septendecim* and *M. cassini*, it has been advantageous to oviposit in the enormously expanded acreages of second-growth woody species: the young sunlit trees are rapidly growing, root/shoot ratios are high (Lyr et al. 1963), and prospects for survival of the nymphs are good. But for *cassini*, in addition, it has often been disastrous to oviposit "as usual" in the ashes, elms, hackberries, and sycamores of floodplain forests when, over the next 17 or 13 years, these forests have been converted into cornfields or the remnants of floodplain forest permanently flooded by dams.

Two possible hypotheses come to mind. The first would be statling if true: (1) Originally *M. cassini* may have had some inherited behavioral pattern that led it to prefer ovipositing in the tree species characteristic of floodplain forests, just as *M. septendecim* now demonstrably prefers to oviposit in upland species. However, during the 150 years or so since European settlement (about 9 or 12 cicada generations), the relatively greater destruction of floodplain

than of upland forests has exerted relatively greater selective pressures on *cassini*, and this has brought about genetic changes affecting its oviposition behavior. That would be rapid evolution indeed.

An alternative hypothesis assumes no genetic changes and is testable: (2) Adult cicadas prefer to oviposit in the twigs of the same plant species on whose roots they fed as nymphs. Most ovipositing females of *septendecim* immigrating to recent second growth (less than 17 or 13 year old) have probably come from the large oaks, hickories, and maples of nearby upland forests, whereas most immigrating *cassini* females have probably come from older second growth, since mature floodplain forests are so scarce. If the females simply tend to stick with whatever they grew up on, this would explain how a population of *cassini* could change its oviposition habits (assuming that they did) so rapidly. This second hypothesis would also explain why the preference of *septendecula* for hickory appears to be stronger where the vegetation is more dominated by hickory, as we mentioned earlier. We plan to test this idea directly with field experiments.

We next ask whether the same pattern is exhibited in our sample of 13-year cicadas (Brood XIX) from Ramsey Lake. Here the second-growth species are mainly roughleaf dogwood, black locust, frosted hawthorn, and black cherry (Table 1). On the null hypothesis of no preference, the contingency-table expected numbers of ovipositing *septendecim* are (79) vs (33) vs (67). Observed were (105) vs (32) vs (42). For *cassini*, we expect (49) vs (21) vs (42) and find (23) vs (22) vs (67). The deviations are highly significant statistically (chi-square is 47.2, $P < 10^{-10}$), and in exactly the same direction as seen with 17-year cicadas. On present evidence, it appears that differences in oviposition preferences between *Magicicada septendecim* and *M. cassini* are the same differences, whether they are 17-year or 13-year cicadas.

To summarize, three hypotheses were anticipated by previous experience and have been corroborated by the data on oviposition available so far: (1) *Magicicada septendecula* prefers hickory more than the other two species do, (2) *M. septendecim* prefers upland forest species more than *M. cassini* does, and (3) there are no differences between 13-year and 17-year cicadas of the same species.

Evidence is accumulating to support the idea that 13-year periodical cicadas evolved from 17-year ones by the same process—4-year accelerations—that gave rise to a succession of 17-year broods 4 years apart (Lloyd and Dybas 1966, White and Lloyd 1975). It appears that 4-year accelerations are still occasionally taking place (Lloyd and White in press, Lloyd and Dybas in prep.). The entire evolutionary process, including the generation of 13-year broods, may have occurred quite recently, possibly since the last glaciation, and may still be going on. If this were so, then it would come as no surprise if

13- and 17-year cicadas of the same species had not evolved ecological differences.

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BOOK REVIEW

Ecological Animal Parasitology. C. R. Kennedy. 163 pp. Halsted Press; John Wiley & Sons, New York. $11.95. 1975.

This is a very concise introduction to the ecology of animal parasites. The book is extremely readable, authoritative, and accurate. The list of references is not very extensive (less than 200), referring to many reviews in which the original references are cited. This practice makes it more difficult and time consuming to find the relevant papers but otherwise detracts little from the value of this book. The volume can be recommended to both undergraduate and graduate students first encountering the problems of parasitology and tropical medicine. The topics discussed are timely and will appeal to experts as well as to newcomers in parasitology.

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Head Capsule Widths of the Walnut Caterpillar[1]

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Abstract: Head capsule widths on intact walnut caterpillar larvae were relatively uniform within an instar. Those from intact larvae compared favorably with widths of head capsules shed during molting for the same instar, for the 1st four instars. Head capsule widths differed from 1 instar to another and indicated that 5 instars constituted the larval stage. Finally, head capsule width can apparently be safely used to identify the instar of field collected walnut caterpillar feeding on pecan foliage in Texas.

The walnut caterpillar, *Datana integerrima* Grote and Robinson, is indigenous to the U.S.A. east of the Rocky Mountains (Haseman 1940) and during epidemic years defoliates trees in the family Juglandaceae over large areas. For the last three years (1973–1975), the walnut caterpillar was epidemic in parts of southcentral and southeast Texas (Harris and Van Cleave 1974). Unprotected pecan trees in these areas of the state were partially to totally defoliated.

The life history of the walnut caterpillar observed during this period generally agrees with that reported by Baerg (1928), Haseman (1940), and Hixson (1941). Diapause is facultative, with 2–3 generations occurring in Texas depending on latitude.

To facilitate field studies of walnut caterpillar biology, including predation, parasitism, feeding, colony mortality etc., a method for field identification of larval instars is needed. Although Dyar (1890) reported that head capsule widths of lepidopterous larvae proceed in a geometric progression as the larvae advance in instar and that head capsule width does not change during a stadium, Gaines and Campbell (1935) noted that the number of instars of *Heliothis zea* Boddie is influenced by its food plant and Peterson and Haessler (1928) observed that the number of instars of *Grapholitha molesta* (Busck) is influenced by food and temperature. Earlier investigators of the walnut caterpillar each reported different larval head capsule width measurements

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(Dyar 1890, Baerg 1928, Haseman 1940, Hixson 1941) and did not include measurement ranges. Baerg (1928) reported measurements for 6 instars from insectary-reared larvae. Preliminary investigations in our own laboratory yielded yet another set of measurements that could not be reconciled completely with those of any previous report. In light of the above, this study was conducted to evaluate the usefulness of head capsule widths in determining the various instars of field collected walnut caterpillar.

MATERIALS AND METHODS

Walnut caterpillar egg masses were collected at various locations and larvae reared in the field on pecan trees at College Station, Brazos County, Texas during the summer months of 1974 and 1975. Completely sclerotized head capsules of all larval instars were severed from the body, or collected from exuvia for measurement. Head capsules from 4th instar exuvia were collected at various times from numerous locations containing endemic and epidemic populations of walnut caterpillar.

The greatest width across each head capsule was measured with an ocular micrometer in a dissecting stereo microscope.

Attempts to rear field-collected colonies in the laboratory were abandoned when it was found that an occasional colony went through 6 instars and that head capsule widths were somewhat variable within and between instars. (This may account for some of the discrepancies noted earlier as Hixson (1941) suggested.) Consequently, all investigations were made on natural or established field colonies.

Larvae, or head capsule exuvia were collected daily from closely observed and marked field colonies from each of 3 generations during the 2 year period of the investigation. Duncan's multiple range test (.05 level) was the statistic used to assess head capsule width differences, 1) within an instar among locations and generations 2) among instars among locations and generations and 3) within an instar between head capsules and head capsule exuvia.

Voucher specimens of head capsules and adult walnut caterpillar have been deposited in the collection of the Entomology Department, Texas A&M University, College Station.

RESULTS AND DISCUSSION

Head capsule widths of the walnut caterpillar, indicated that this species has 5 instars (Table 1). Typical means and standard deviations calculated for 20 walnut caterpillar head capsules for each instar reared at College Station are 0.443 ± .017, 0.836 ± .023, 1.413 ± .064, 2.638 ± .15 and 4.349 ± 183 mm for 1st–5th instars, respectively (1st summer generation, 1974). Comparing these measurements to those of succeeding generations indicated there was no

TABLE 1. Head capsule width measurements of walnut caterpillar that have been pooled form all locations and generations in Texas.

Instar	Range (mm)	Mean (mm)
1	.391– .495	.445
2	.716–1.000	.839
3	1.061–1.650	1.400
4	1.929–3.190	2.620
5	3.748–5.000	4.365

overlap in head capsule width from one instar to another regardless of generation. Daily measurements of 10 head capsules per instar indicated no differences in width during an instar.

Head capsules exuvia of the first 4 instars remain whole, whereas those of the 5th instar are usually split. A camparison of head capsule width to the head capsule exuvium of the same instar indicated no differences in size for the first 4 instars.

Head capsules collected from 4th instar exuvia at different locations, some containing endemic and some epidemic populations of walnut caterpillar, were relatively distinct from those of the other 4 instars in width. Head capsule widths from 4th instar larvae in endemic populations were also indistinguishable from those in epidemic populations.

The data indicate that the walnut caterpillar has 5 distinct instars on pecan in all 3 field generations in Texas and that the relative uniformity of head capsule widths within an instar, among colonies, generations, and years and within the 4th instar among locations and endemic and epidemic populations, makes head capsule width useful in identifying the instar of field-collected walnut caterpillar in Texas.

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Sense Organs on the Antennal Flagellum of a Bird Louse (Mallophaga)

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Abstract: From 25 to 30 sense organs are present on each antennal flagellum of a female bird louse, *Craspedorrhynchus americanus* Emerson. About half of them are clustered at the apex of the third (distal) flagellar subsegment. Tactile hairs, thick-walled chemoreceptors, thin-walled chemoreceptors and coeloconic chemoreceptors can be identified.

The present paper is one of a series, begun about 20 years ago, in which an attempt is being made to examine the flagellar sence organs of one or more species from each order of insects.

The mallophagan antennal flagellum is especially difficult to study because of its very small size. When isolated and unstained it can not be seen with the naked eye. There is almost no literature on the antennal sense organs of the Mallophaga. Occasionally, outline drawings of the antenna are included in systematic papers but at a magnification so low as to give only a superficial impression of the sense organs present. One of the best is that of Essig (fig. 71e, 1942) who includes a drawing of the antenna of *Menodon stramineum* in his description of the order. Some of the sense organs are shown but there are no comments on them either in the text or in the legends for the figures.

MATERIALS AND METHODS

The material examined here consisted of nine adult females of the species *Craspedorrhynchus americanus* Emerson. All had been taken from a red-tailed hawk, *Buteo jamaicensis*, and fixed in Bouins solution.

Since so few specimens were available, the methods used to study them were, necessarily, limited. Most of the individuals were prepared as whole mounts. A few were treated externally with a 0.5% solution of crystal violet in order to identify pores in the cuticle of sense organs (Slifer, 1960). Such openings are characteristic of insect chemoreceptors (Slifer, 1970).

Acknowledgements: The material was given to the author in 1962 by Dr. Nancy S. Mueller, then at the University of Wisconsin and now at North Carolina Central University at Durham, North Carolina. Dr. K. C. Emerson, of Arlington, Virgina, very kindly identified the specimens. Dr. Shih, at the University of Iowa, was most helpful in obtaining the scanning electron micrographs.

An antenna from one specimen was stained in acetocarmine and those from another in borax carmine in an attempt to locate sensory neurons and other cells within the antennal lumen. The results were helpful, but not conclusive, in determining the number of neurons present for each sense organ. Another antenna was embedded in paraffin, sectioned and stained with Heidenhain's iron-hemotoxylin. One of the antennae from an individual that had been treated with crystal violet was removed from the slide, soaked in a weak solution of KOH over night and then re-mounted. After this preparation had been studied the antenna was removed again from the slide, embedded in paraffin, cut at 7 μ and the sections stained with Mallory's connective tissue stain.

Another individual was dehydrated, cleared in xylol, dried and examined with the Cambridge scanning electron microscope in the Department of Zoology at the University of Iowa. Debris on the antenna was difficult to remove manually and sonic cleaning was not attempted because of the few specimens on hand.

RESULTS AND DISCUSSION

The mean length of thirteen antennal flagella from *Craspedorrhynchus americanus* females was 111 μ (range 100 to 127 μ). The flagellum is composed of three subsegments of which the first is slightly longer than the other two and the third is the narrowest of the three (fig. 1). The greater part of the wall of a subsegment is heavy but tapers abruptly to a thin membrane between subsegments and is not uniform in depth at a particular level. For example, in a single cross section of the flagellum the wall was 12 μ deep in most regions but decreased to 2 μ at one point.

The conventional terminology for the description of an insect antenna refers to it as if it were extended anteriorly from the front of the head. In *C. americanus* the antennae would be prevented from assuming this position since there is a wide projection of the head wall in front of each antennal base (fig. 5). In the following description this disability will be ignored and the antennae treated as if they could be extended forward.

All of the sense organs on the *first subsegment* are slender and have a tip that tapers to a fine point. They are not affected by a solution of crystal violet applied to the external surface. These are characteristics of tactile hairs. The largest, 24 μ, or less, in length, is located on the ventral side, close to the distal end of the subsegment (fig. 1). From three to five smaller tactile hairs are also present on or near the dorsal surface.

Either two or three tactile hairs were found on the *second subsegment* (fig. 1). As on the first subsegment, the longest was located on the ventral side at the extreme distal border. A second was present on the side opposite the first and a third was sometimes present not far from it.

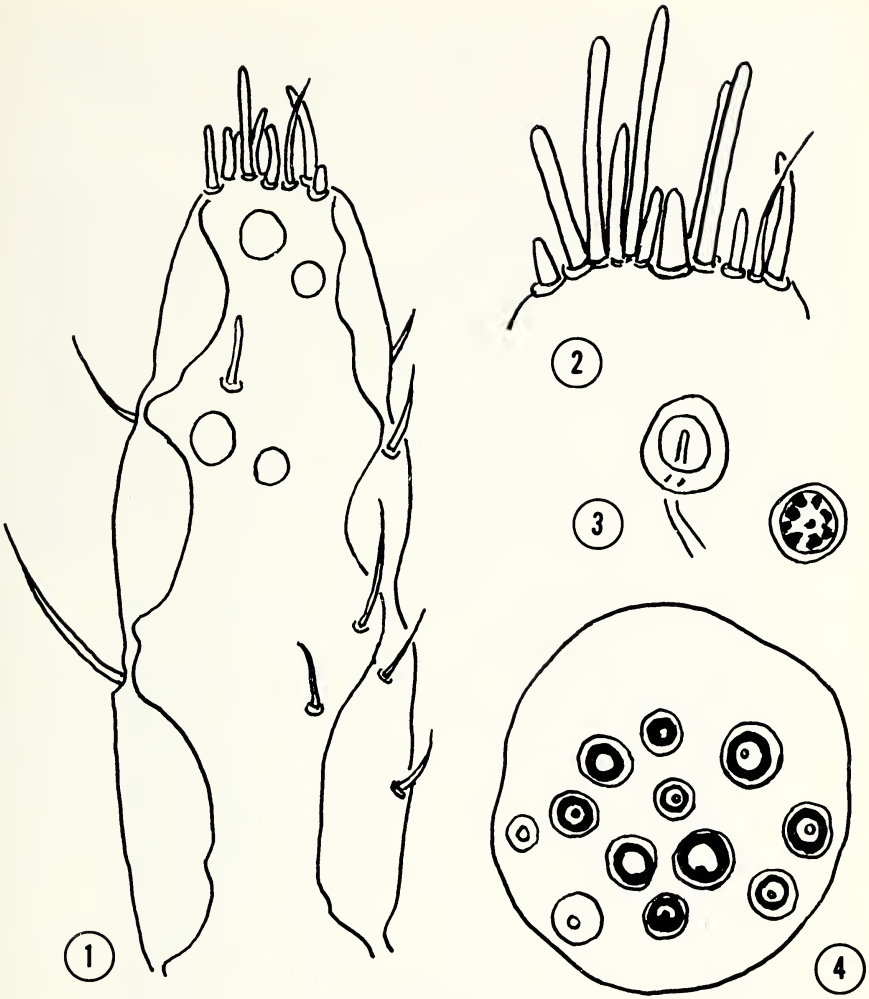


Fig. 1. Lateral view of antennal flagellum of female bird louse. Tuft, composed of thick-walled and thin-walled chemoreceptors and a tactile hair, lies at apex of third subsegment. Circular areas in second and third subsegments are coeloconic chemoreceptors. A single thick-walled chemoreceptor is present near the proximal edge of the third subsegment. All other sense organs are tactile hairs. × 1000.

Fig. 2. Tuft of sense organs from third subsegment. A short, broad thin-walled chemoreceptor lies at the left edge and a larger one close to center of group. A thin tactile hair is second from the edge at right. The others are thick-walled chemoreceptors. × 2000.

Fig. 3. Two coeloconic chemoreceptors from second subsegment as seen in surface view. The peg and the cuticular sheath attached to its base are shown in the sensillum at the left. The cavity of the other contains many small particles that have entered through the opening in the roof. × 2000.

Fig. 4. Cross section through tip of third subsegment to show bases and sockets of twelve sense organs. The socket at the left and that in the lower left corner were added from the next section proximal to this one. × 2000.

In addition to the tactile hairs, two roughly circular, clear areas are visible on the second subsegment on the lateral surface and near the distal end (figs. 1, 3). They are best seen in an antenna that has been isolated and mounted lateral side up. The one farthest anterior is slightly larger than the other. These are coeloconic sense organs. Each contains a minute peg, about 3 μ long, which lies in a cavity from 4 to 9 μ across. The peg stains at the tip with a dye applied externally. This indicates that a pore is present there and that the structure is a chemoreceptor. A cuticular sheath of the type associated with the coeloconic sense organs of species of insects from other orders encloses the dendrites that extend into the peg. Very fine particles, probably originating from the skin and feathers of the host, may enter through the opening in the roof of the chamber and be trapped in the cavity (fig. 3). They stain with crystal violet and may obscure the peg.

Four circular areas are outlined in Essig's drawing of the antenna of *Menopon stramineum* (fig. 71e, 1942). It is possible that these are coeloconic sense organs of the type described here. However, of the four, two are located, in Essig's figure, on the pedicel and one each on subsegments one and two. This arrangement is very different from that described here.

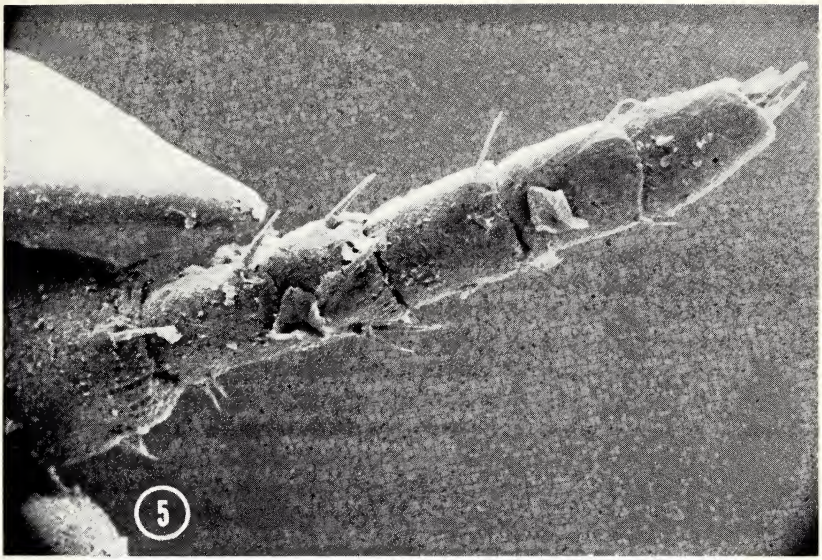
It is interesting that Miller (1970a, 1970b, 1971) has reported that a single coeloconic sensillum is present on the terminal subsegment and on the one just proximal to it in several species of Anoplura. His studies were all made with the scanning electron microscope. Except for their very different mouth parts, the Mallophaga and the Anoplura share many characteristics and have been placed in the same order by some systematists (Ross, 1956). The occurrence of conspicuous coeloconic chemoreceptors on the last two subsegments of species from both of these orders adds one more feature to those that they have in common.

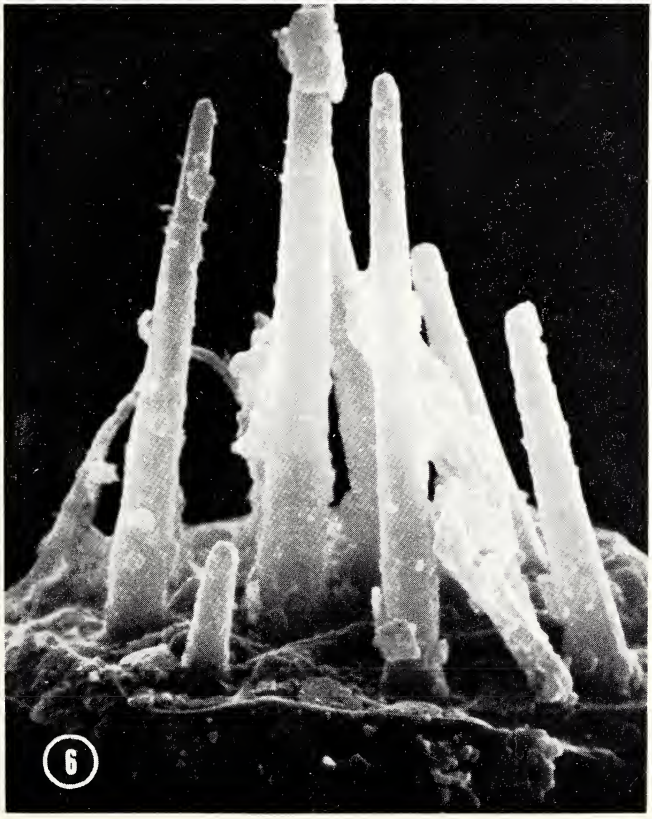
The *third subsegment* has on it a larger number and greater variety of sense organs than do those proximal to it. Most of them are concentrated in a tuft at the apex. As in the second subsegment, two coeloconic chemoreceptors are present on the lateral surface and close to the distal end. Two small tactile hairs, from 3 to 10 μ long may be seen on the dorsal surface but were not always found. A single stout hair, from 9 to 16 μ long occurs on the ventro-lateral surface. This is usually, but not always, close to the proximal border of the subsegment.

→

FIG. 5. Scanning electron micrograph of left antenna showing ventral surface of scape, pedicel and three flagellar subsegments. A projection of the side of the head extends to the middle of the pedicel and would prevent forward extension of the antenna. A small pore may be seen on the third subsegment. × 540.

FIG. 6. Scanning electron micrograph of apex of third subsegment showing tuft of sense organs. The smaller of the two thin-walled chemoreceptors is in the front row and the slender tactile hair is near the left edge. The remaining sense organs are thick-walled chemoreceptors. Several sense organs are hidden by those shown. × 5500.


5


6

It stains at the tip with crystal violet and so must be classed as a thick-walled chemoreceptor.

A pore, about one micron in diameter, may be seen in fig. 5. A pair of similar structures on the terminal subsegment of several species of Anoplura examined by Miller (1969, 1971) have been referred to as pore organs. The anopluran pore is surrounded by a ring of fine grooves that radiate from it. Grooves were absent in *C. americanus* and the pore looks very much like the opening at the cuticular surface of the duct of an epidermal gland. Such pores are commonly present on insect antennae, as well as elsewhere on the body. If the pore in Miller's material is a gland opening, the slits surrounding the pore may aid in the spreading of a secretion. Figure 7 in Miller's paper (1969) suggests that this may occur. Whether or not this is the proper interpretation could best be determined with sections examined with the transmission electron microscope.

The conspicuous cluster of hairs at the distal end of the third subsegment is composed of two thin-walled chemoreceptors, from 7 to 9 thick-walled chemoreceptors and one tactile hair. All are set close together in well-developed sockets in a thin membrane (figs. 2, 4, 6). The blunt-tipped thick-walled chemoreceptors range in length from 6 to 22 μ. They stain at the tip with crystal violet. This indicates that a pore is located here at which the distal ends of sensory dendrites are exposed. The thin-walled chemoreceptors, in contrast, stain over their entire surface. Many small pores penetrate the walls of such structures in other species of insects and the lumen is filled with the branches of sensory dendrites (Slifer, 1970).

The thin-walled pegs vary in length from 3 to 9 μ. The larger one is located on the dorsal surface and the other is in the dorso-lateral region. The slender tactile hair ranges in length from 7 to 15 μ. It is unaffected by stain applied externally.

A small number of sensory neurons, accompanied by their sheath cells, lie in the lumen of the third subsegment. These were best seen in the acetocarmine and borax carmine whole mounts and in the sections stained with Heidenhain's iron-hemotoxylin. Since approximately 16 sense organs are present on this subsegment, the number of neurons innervating each receptor must be small. It was not possible to determine the number exactly.

In summary, the antennal flagellum of a female *Craspedorrhynchus americanus* is well provided with tactile hairs and chemoreceptors. All of them are of types that have been described previously for species of insects from other orders.

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BOOK REVIEW

Insect Diseases. George E. Cantwell, ed. 2 volumes. 595 pp. + 21 pp. glossary. Marcel Dekker, New York. $54.00. 1974.

Interest in insect diseases has increased in recent years. The primary reason for it is the attention given insect pathogens as potential biological control agents. The resistance of insect vectors of disease agents and of agricultural pests to chemical insecticides, coupled with the public awareness of the environmental pollution and the concern about the continuous use of chemical insecticides made the large scale uses of "living insecticides" a reality. There is now a definite need for modern, comprehensive descriptions of insect pathogens and diseases, for students in colleges and universities as well as for researchers. The scholarly treatment of this subject by the late Prof. Steinhaus is partly outdated and the remaining copies of the classic 2 volumes are quite expensive. Cantwell's volumes are concise but also expensive, even though the books have been produced from non-justified typescripts by camera copy. The first volume contains 5 chapters: Diagnostic Techniques by G. M. Thomas; Virus and Rickettsial Diseases by J. L. Vaughn; Bacterial Diseases by R. M. Faust; Mycoses by J. N. Bell, and Protozoan Infections by W. M. Brooks. The six chapters of the second volume comprise: Symbiology-Mutualism between Arthropods and Microorganisms, by G. M. Boush and H. C. Coppel; Nematode Infections by N. R. Nickle; Radiation, Neoplasms, Carcinogenic Chemicals, and Insects by J. C. Harshberger; Hormonal-induced Pathologies by W. F. Walker; Genetic Pathology by P. J. Bryant; and Honey Bee Diseases, Parasites, and Pests by G. E. Cantwell. The fact that one has to look for the index to the first volume at the end of the second indicates that these volumes were prepared as a single book, then split arbitrarily, disregarding the need for separate indices. Apart from this inconvenience, the volumes provide a useful introductory text covering the entire field of insect pathology for undergraduate and graduate entomology students. The inclusion of nearly 2 dozen laboratory exercises provides a handy guide to tests that were chosen so as to require only simple equipment. Each chapter is followed by an extensive bibliography. The overview of various areas of insect pathology is good and the text can be recommended for an introductory level course.

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Evolutionary Trends in *Cryptocercus punctulatus* (Blattaria: Cryptocercidae)

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Abstract: First instar nymphs of *Cryptocercus punctulatus* are eyeless. The reduced eyes of adults may result from the morphogenetic process of retardation. The blind condition of the youngest nymphs is an adaptation to life in rotting logs and perhaps also represents a preadaptation to life in the termite niche present in a common ancestor of *Cryptocercus* and the termites. The over-all resemblance between first instar nymphs of *C. punctulaus* and termites suggests the neotenic origin of the latter from a blattarian ancestor.

Cockroach systematists have virtually ignored nymphal characters in classifications of the Blattaria. The most widely accepted taxonomic scheme (McKittrick, 1964), is based on adult characters, mostly those of the genitalia. In a recent numerical taxonomic study of adult and nymphal cockroaches, Huber (1974) used a wide range of external morphological characters including many which are ontogenetically homologous in all instars. This enabled him to construct and compare classifications based entirely on nymphal characters with classifications based on adult characters. The nymphal stages produced classifications which were congruent with those of McKittrick (1964) and although obviously diagnostic characters were not found in the nymphs, familial and subfamilial divisions could be detected.

During his study, Huber (1974) made the surprising discovery that, unlike other Blattaria, the first instar nymphs of *Cryptocercus punctulatus* Scudder lack compound eyes. Since this species is regarded by McKittrick (1964, 1965) as the most primitive living cockroach, its phenetic placement in phenograms and centroid component models (Huber, 1974) was of particular interest. Apparently, the eyeless condition did not have much effect on the position of *C. punctulatus* in the classifications of the small nymphs. The eyes of adult *C. punctulatus* are reduced in size compared with other species of cockroaches (Crampton, 1932; Beier, 1974, Fig. 15). Are its eyes smaller because they have had fewer instars in which to grow? Mackerras (1967) refers to various

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other species of cockroaches in which the eyes are reduced or absent. Nothing is known about the ontogeny of eye development in these troglobiont forms. De Beer (1958) proposed the concept of *retardation* as one explanation for the reduction of an adult structure. Perhaps the reduced eyes of *C. punctulatus* are a product of such a process.

The Isoptera are thought to have evolved from Blattaria (McKittrick, 1964; Tillyard, 1936; Brosut, 1973; Emerson, 1961; Rau, 1941). The literature has been surveyed by Wilson (1971:103). Thus, it is interesting to note that early instars of termites also lack compound eyes (Weesner, 1969). The development of compound eyes has been histologically investigated in some of the termites (reviewed by Richard, 1969). In second instar *Cryptocercus*, the eye appears as a small (one-third the size of the antennal socket) and poorly pigmented (reddish-brown) structure. During eye development in the termites (Richard, 1969:179), a reddish-brown pigment appears in the seventh stage. The eye later darkens to a deep brown in both termites and in *C. punctulatus*. A comparative study of eye ontogeny in *Cryptocercus* and the termites would be profitable.

Although *Cryptocercus* is regarded as primitive among cockroaches, it nevertheless possesses many unusual, even unique, characters. Winglessness, subsocial life, the presence of flagellates in the gut for the digestion of cellulose and the structure of the proventriculus of *C. punctulatus* are all adaptations for life in rotting logs and for xylophagy. The blindness of the first instar and the reduced condition of the eye in later instars could be added to this list. All of these features may be regarded as adaptations to life in the termite niche. Perhaps these were present as preadaptations in a common ancestor of *Cryptocercus* and termites. First instar *C. punctulatus* moreover bear a remarkable, even startling, resemblance in size, shape and appearance to many termites (e.g., *Reticulitermes* sp.) (Cleveland et al., 1934). Perhaps in such cockroaches (except for winglessness), we have a plausible model of the blattarian ancestor of the Isoptera.

It is possible to speculate on the mode of evolution which produced the termites. Neoteny seems to have been a significant process during orthopteroid evolution (reviewed by Huber, 1974). Richard (1969) notes that adult termite ommatidia possess many embryonic characters. This fact together with the similarities mentioned above strongly suggests a neotenic derivation of the Isoptera from a *Cryptocercus*-like cockroach ancestor. A numerical phenetic study of suitably chosen termites and nymphal cockroaches should yield new insights into the relationships between these groups.

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BOOK REVIEW

Insect Hormones. V. J. A. Novak. Second English Edition. 600 pp. Chapman & Hall, London; Halsted Press; John Wiley & Sons, New York. $49.50. 1975.

Rarely does a textbook fulfill a real need, rather than just increase the rapidly growing literature. Novak's book is one of these welcome, rare contributions. It is actually the English translation of his 4th edition which appeared in Czech, and it is in many ways a remarkable treatese. It deals briefly with the history of insect endocrinology, then describes the techniques used in research, including tissue and organ culture. Ecdysone, the juvenile hormone, and the corpora cardiaca hormones are described in the 3rd chapter on 120 pages. This is followed by a discussion of natural and synthetic substances with hormone activity. The role of hormones in morphogenesis and diapause, the neurohormones, protohormones, exohormones, and the substances with allegedly hormonal characteristics occupy 100 pages. A separate chapter is devoted to the effects of insect hormones on noninsects. The book concludes with a stimulating discussion about the theoretical and practical significance of insect hormones. There is an extensive list of references, a good subject index and an author index. This is a remarkable and valuable book, very useful as a reference, amply documented, that can be considered a major and unique addition to the literature on invertebrate endocrinology. Novak's book will remain an important summary of the subject for years to come for all who are working with insect endocrinology.

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Parasitoids and Diseases of the Elm Spanworm

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Abstract: Nine previously unreported primary parasitoids and possibly one hyperparasite were isolated from the elm spanworm, *Ennomos subsignarius* (Hübner) (Lepidoptera: Geometridae), during an outbreak in Connecticut in the early 1970s. Primary parasitoids included *Ablerus clisiocampae* (Ashmead) (Hymenoptera: Eulophidae), *Apanteles murtfeldtae* Ashmead and *Meteorus* sp. (Hymenoptera: Braconidae), *Aphanistes* sp. and *Phaeogenes mellinus* (Provancher) (Hymenoptera: Ichneumonidae), *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae), *Muscina stabulans* (Fallen) (Diptera: Muscidae), *Boettcheria cimbicis* (Townsend) (Diptera: Sarcophagidae), and *Winthemia* sp. (Diptera: Tachinidae). *Astiphromma pectorale* Ashmead (Hymenoptera: Ichneumonidae), possibly a hyperparasite, was recovered from one pupa. Incidence of parasitism of these and other parasitoids along with the chronological appearance of the more abundant larval and pupal parasitoids is presented. A review of all reported parasitoids and diseases of the elm spanworm is given.

INTRODUCTION

The elm spanworm, *Ennomos subsignarius* (Hübner) (Lepidoptera: Geometridae), reached outbreak levels over large acreages of woodland in Connecticut between 1970–72 (Anderson and Gould, 1974), but ultimately the outbreak collapsed primarily because of parasitism by the egg parasitoid, *Ooencyrtus ennomophagus* Yoshimoto (Hymenoptera: Encyrtidae)[1] (Kaya and Anderson, 1972, 1974a). Samples of elm spanworm eggs, larvae and pupae were collected from various areas of the outbreak from 1971–73, brought to the laboratory and reared to isolate and identify disease organisms and parasitoids. Incidence of parasitism of eggs by *O. ennomophagus* and *Telenomus alsophilae*[2] Viereck (Hymenoptera: Scelionidae) and larvae by *Actia ontario* Curran (Diptera:

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[1] Referred to as *Ooencyrthus* sp., *O. ennomus*, and *O. clisiocampae* (Ashmead) by the authors.

[2] May be new species (P. M. Marsh).

Tachinidae) have been published previously (Kaya and Anderson, 1972, 1974a; Anderson and Kaya, 1974a). The incidence of parasitism of the elm spanworm by other enemies and their chronological appearance, and a review of all reported parasitoids and diseases of this important but infrequent defoliator of hardwoods in eastern North America are reported herein.

METHODS

Collections of elm spanworm eggs and methods of determining parasitism were described by Kaya and Anderson (1972, 1974a), and collections and rearing methods of elm spanworm larvae were described by Anderson and Kaya (1974a). Prepupae and pupae collected in the field were kept individually in 1 oz cream cups. All larvae and pupae collected were kept until they died or until the adult elm spanworm or parasitoid emerged. If a parasitoid emerged, it was considered the sole cause of death. Incidence of parasitism by various parasitoids was determined. Larvae and pupae that died from causes other than parasitism were dissected and various organs examined with a phase contrast microscope for presence of disease organisms. Larvae were collected from 14 sites in 5 counties in 1972 and 4 sites in 4 counties in 1973. Pupae were collected from 11 sites in 4 counties in 1972 and 2 sites in 2 counties in 1973.

We were unsuccessful in rearing most tachinids to adults, thus identification was often based upon puparial characters. Incidence of parasitism by tachinids in this paper, with the exception of *A. ontario*, is recorded only to the probable genus.

RESULTS AND DISCUSSION

Egg parasitoids. The importance of *O. ennomophagus* and *T. alsophilae* during the outbreak in Connecticut has been reported by Kaya and Anderson (1972, 1974a) and Anderson and Kaya (1973a, 1974a). A third parasitoid, *Ablerus clisiocampae* (Ashmead) (Hymenoptera: Eulophidae), a species not previously recovered from the elm spanworm, was isolated from 3 of 6 egg masses collected at one site in May, 1972. Five of these egg parasitoids emerged from each of 2 egg masses and 3 emerged from the third egg mass. The egg masses were also parasitized by *O. ennomophagus* and *T. alsophilae*. Emergence holes in eggs verified that indeed this parasitoid emerged from the elm spanworm and not from some other insect that might have been on the bark. Inasmuch as over 200,000 eggs were examined during this study, *A. clisiocampae*, which has frequently been recovered from *Malacosoma* spp. (Lepidoptera: Lasiocampidae) (Witter and Kulman, 1972), is not considered to be an important parasitoid of the elm spanworm.

Larval and pupal parasitoids. No parasitoids were recovered from larvae collected in the first and second instars. A total of 363 1st and 2nd instars were collected from 5 sites in 1972, of which 208 died from unknown causes. Parasit-

oids were recovered from larvae collected in the 3rd and subsequent instars and from pupae. Fedde (1964) also reported that the late instars and pupae were attacked most frequently by parasitoids.

A previously unreported *Meteorus* sp. (Hymenoptera: Branconidae) was recovered from larvae collected in the 3rd through 5th instars from 2 sites in 1973. Parasitization was less than 1%.

Apanteles murtfeldtae Ashmead (Hymenoptera: Braconidae), a gregarious and previously unreported parasitoid of the elm spanworm, was recovered from larvae collected as 3rd, 4th and 5th instars. Hosts were killed in all of these instars. Parasitization was less than 2%.

Muscina stabulans (Fallen) (Diptera: Muscidae), a facultative parasitoid of lepidopterous larvae (Lewallen, 1952), but not previously reported as a parasitoid of the elm spanworm, was recovered from 4 5th-instar larvae. Up to 4 puparia were recovered from a single host.

Tachinids were the most frequently recovered parasitoids. They were isolated from larvae collected in the 3rd instar but most frequently in larvae collected in the 4th and 5th instars and from pupae. Parasitization was highest by *A. ontario* as reported by Anderson and Kaya (1974a) and shown in Table 1. Few host larvae collected in the 3rd instar were parasitized. Many 4th instars were parasitized by *A. ontario* and by tachinids which could not be identified. One 4th instar host larva was parasitized by *Eusisyropa*. Fifth instars were parasitized most frequently by *A. ontario*, to a lesser extent by *Eusisyropa* and rarely by *Winthemia* and *Euexorista* (Table 1). Hosts parasitized by *Eusisyropa*, *Winthemia* and *Euexorista* died as pupae. Parasitization by all tachinids was greater in 1973 than in 1972 and ranged as high as 64.3% in larvae collected in the 5th instar. Field collected pupae were primarily parasitized by *Eusisyropa*. Adults of *Euexorista futilis* (Osten Sacken) were obtained from elm spanworm pupae collected in 1971.

Two species of sarcophagids, *Boettcheria cimbicis* (Townsend), a previously unreported parasitoid of the elm spanworm, and *Sarcophaga houghi* Aldrich, were recovered. Parasitization by sarcophagids was usually less than 1% but reached 45% in one site. It is conjecture whether these sarcophagids are primary parasitoids or scavengers (Campbell, 1963).

Brachymeria intermedia (Nees) (Hymenoptera: Chalcididae), an introduced parasitoid of the gypsy moth, was recovered from pupae. Parasitization was less than 2%.

Single specimens of *Phaeogenes mellinus* (Provancher) and *Aphanistes* sp., both previously unreported ichneumonid parasitoids of the elm spanworm, were recovered from pupae.

Astiphromma pectorale Ashmead (Hymenoptera: Ichneumonidae), possibly a hyperparasite of *Itoplectis conquisitor* (Say) (Hymenoptera: Ichneumonidae), was isolated from 1 pupa of the elm spanworm.

Table 1. Changes in larval and pupal parasitoid numbers in hosts collected in the field through the 1972 and 1973 seasons in Connecticut.

Date	Most abundant host instar	Total collected	% total parasitism	% parasitism by species												
				Actia ontario	*Eusisyropa*	*Euexorista*	*Winthemia*	Unknown Tachinidae	Sarcophagidae	*Brachymeria compsilurae*	*Apanteles murtfeldtae*	*Itoplectis conquisitor*	*Meteorus*	*Brachymeria intermedia*	*Muscina srabulans*	Other parasitoids
						1972							0	0	0	0
May 15	I	236	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 22	II	232	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 28	III, IV	257	1.2	0	0.4	0	0	0.8	0	0	0	0	0	0	0	0
June 5	IV	104	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June 12	IV, V	397	28.5	16.9	4.0	0.1	0	7.2	0	0	0.3	0	0	0	0	0
June 19	V	897	19.2	13.3	2.5	0	0.1	2.9	0	4.1*	0	0	0	0	0.4	0
June 26	V, P	689	22.4	7.1	9.9	0.1	0.1	4.2	0.2	0.7	0	0	0	0	0	0.8
July 3	P	1511	2.8	0.1	1.0	0	0.1	0.8	0.7	33.3	0	0	0	0	0	0.1
July 10	P	221	14.5	0	1.4	0	0	0.9	8.6	20.0	0	2.3	0	1.3	0	0
						1973							0	0	0	0
June 7	IV, V	503	41.4	24.1	0	0	0	14.3	0	0	1.4	0	0.6	0	0	1.0
June 12	V	598	58.5	46.3	0	0	0	10.4	0	0	1.0	0	0	0	0	0.8
June 19	V	235	40.9	32.3	0	0	0	6.0	0	0	1.7	0	0	0	0	0.9
June 26	P	533	9.6	3.7	0.8	0	0	3.2	0	9.3	1.1	0.4	0	0	0	0.4

* Since *B. compsilurae* is a hyperparasite, percentages are based upon the number of elm spanworms parasitized by tachinids.

The hyperparasite, *Brachymeria compsilurae* (Crawford) (Hymenoptera: Chalcididae), was collected from several sites and found to parasitize the tachinids, *Winthemia*, *Eusisyropa*, *A. ontario* and *Euexorista*. Five of these hyperparasites were recovered from 5th instars, thereby showing that this hyperparasite is capable of finding its host within parasitized elm spanworm larvae. The majority, however, were recovered from elm spanworms collected as pupae. Parasitization of tachinid puparia from 5th instar elm spanworm ranged as high as 25% in one site. In collections comprised entirely of pupae, parasitization of puparia was as high as 19% in one location.

The chronology of parasitoid attack of elm spanworm larvae and pupae is shown in Table 1. Large numbers of 4th and 5th instars were parasitized on June 12, 1972. *A. ontario*, and to a lesser extent, *Eusisyropa*, were the predominant parasitoids. *A. ontario* parasitizes mainly 4th and 5th instars (Anderson and Kaya, 1974a), but it is not known if earlier instars were not parasitized because they are unsuitable hosts or if adult parasitoids were absent at that time. *A. ontario* continued to be abundant into the last of June, though parasitization gradually declined. Sarcophagids were most abundant during July. *B. compsilurae*, a hyperparasite, did not appear in collections until the middle of June when larvae were predominantly in the 5th instar. Parasitization then remained at a fairly uniform level throughout the remainder of the season. This hyperparasite appeared shortly after tachinids became abundant in the samples. *I. conquisitor* and *B. intermedia* appeared only in the last pupal collection.

In 1973, collections did not begin until larvae were predominantly in the 4th and 5th instars during the week of June 7. Abundance of *A. ontario* reached a peak and *B. compsilurae* appeared 1 week later than in 1972. *A. murtfeldtae* was recovered from larvae throughout June. *Meteorus* sp. appeared only in the June 7 collection. *I. conquisitor* was collected 2 weeks earlier in 1973 than in 1972.

Primary pathogens of larvae. Over 500 larvae were examined microscopically in 1972 and 1973 and none was found infected with a disease organism.

Parasitoids and diseases of the elm spanworm throughout its range. Many parasitoids have been recovered from the elm spanworm since Thompson (1945) catalogued its parasitoids. A complete list of the known parasitoids of the elm spanworm that we could find in the literature is given in Table 2. At least 42 primary parasitoids and 3 hyperparasites have been recorded. *O. ennomophagus* has been the most extensively studied parasitoid and offers the most promise for managing host populations (Anderson and Kaya, 1973a, b, 1974a, b, 1975; Kaya, 1972; Kaya and Anderson, 1972, 1974a, b, ms. in press).

There have been no verified published reports of isolations of naturally occurring disease organisms of the elm spanworm. Drooz (1965) reported the susceptibility of elm spanworm larvae to the fungus, *Paecilomyces farinosus*

TABLE 2. Insect parasitoids of the elm spanworm.

Family		Host stage attacked	Reference
HYMENOPTERA			
Encyrtidae	*Ooencyrtus ennomophagus* Yoshimoto[1]	Egg	Kaya and Anderson, 1972, 1974a, ms. in press; Anderson and Kaya, 1973a; Yoshimoto, 1975
Scelionidae	*Telenomus alsophilae* Viereck[2]	Egg	Drooz, 1964; Ciesla, 1964a, 1965; Anderson and Kaya, 1973a, 1974a
	Telenomus sp.	Egg	Knull, 1932
Mymaridae	*Anagrus* sp.	Egg	Ciesla, 1964a
Eulophidae	*Ablerus clisiocampae* (Ashmead)	Egg	present paper
	Euplectrus sp.	Larva	Schaffner and Griswold, 1934
Braconidae	*Apanteles murtfeldtae* Ashmead	Larva	present paper
	Meteorus sp.	Larva	present paper
	Rogas sp.	Larva	Raizenne, 1952
	Macrocentrus iridescens French	Larva	French, 1880
Ichneumonidae	*Apechthis picticornis* Cresson	Larva	Schaffner and Griswold, 1934
	Glypta simplicipes Cresson	Larva	Schaffner and Griswold, 1934
	Hyposoter flavipes Provancher	Larva	Schaffner and Griswold, 1934
	Itoplectis conquisitor (Say)	Larva, Pupa	Schaffner and Griswold, 1934; Ciesla, 1964b; Plumb and Friend, 1938; Knull, 1932; Davis, 1960; present paper
	Casinaria geometrae Walley	Unknown	Raizenne, 1952
	Theronia atalantae (Poda)	Pupa	Knull, 1932; Muesebeck et al., 1951
	Aphanistes sp.	Pupa	present paper
	Phaeogenes mellinus (Provancher)	Pupa	present paper
	Pimplopterus sp.	Unknown	Davis, 1960
	Scambus hispae (Harris)	Unknown	Davis, 1960; Muesebeck et al., 1951; Plumb and Friend, 1938
	Astiphromma pectorale Ashmead[3]	Pupa	present paper
Chalcididae	*Brachymeria intermedia* (Nees)	Pupa	present paper
	Brachymeria ovata (Say)	Larva, Pupa	Fedde, 1964; Davis, 1960; Ciesla, 1964b
	Brachymeria compsilurae (Crawford)[4]	Larva, Pupa	Knull, 1932; present paper
	Brachymeria sp.		Plumb and Friend, 1938
Pteromalidae	*Dibrachys cavus* (Walker)[4]	Pupa	Plumb and Friend, 1938
DIPTERA			
Muscidae	*Muscina stabulans* (Fallen)	Larva	present paper
Sarcophagidae	*Boettcheria cimbicis* (Townsend)	Larva	present paper
	Sarcophaga houghi Aldrich	Pupa	Knull, 1932; present paper; Davis, 1960

Table 2. (continued)

Family		Host stage attacked	Reference
	Sarcophaga aldrichi Parker	Unknown	Davis, 1962
	Boettcheria latisterna Parker	Unknown	Knull, 1932
	Helicobia rapax (Walker)	Unknown	Davis, 1960
Tachinidae	*Actia ontario* Curran	Larva	Raizenne, 1952; Anderson and Kaya, 1974a; present paper
	Actia nr. *palloris* Coquillet	Larva	Schaffner and Griswold, 1934
	Compsilura concinnata (Meigen)	Larva	Schaffner and Griswold, 1934; Mc Gugan and Coppel, 1962
	Achaetoneura aletiae (Riley)	Unknown	Davis, 1960
	Chaetogaedia analis (Wulp)	Unknown	Davis, 1960
	Euphorocera floridensis Townsend	Unknown	Davis, 1960
	Eusisyropa blanda (Osten Sacken)	Larva	Knull, 1932; Davis, 1960; Ciesla, 1964b; Schaffner and Griswold, 1934
	Eusisyropa sp.	Larva	present paper
	Xanthoernestia sp.	Unknown	Davis, 1960
	Madremyia saundersii Will	Larva	Schaffner and Griswold, 1934
	Euexorista futilis (Osten Sacken)	Larva	Schaffner and Griswold, 1934; present paper
	Euexorista sp.	Larva	present paper
	Phryxe vulgaris (Fallen)	Larva	Schaffner and Griswold, 1934
	Winthemia sp.	Larva	present paper
	Tachinomyia nigricans (Webber)	Unknown	Raizenne, 1952
	Blondelia eufitchiae (Townsend)	Unknown	Raizenne, 1952
	Eusisyropa virilis (Aldrich and Webber)	Unknown	Aldrich and Webber, 1924

[1] Referred to as *Ooencyrtus* sp., *O. ennomus* and *O. clisiocampae* by the authors.
[2] May be an undescribed species (P. M. Marsh, personal communication).
[3] May be a hyperparasite of *Itoplectis* (R. W. Carlson, personal communication).
[4] Hyperparasites.

(Dickson ex Fries) Brown and Smith, under laboratory conditions. Larvae are highly susceptible to commercial formulations of *Bacillus thuringiensis* Berliner applied either by ground spraying equipment or by plane (Dunbar and Kaya, 1972, and Dunbar *et al.*, 1973).

Viral diseases have been reported from the elm spanworm, but there is no clear evidence to substantiate their presence. Dietz (1925) reported a wilt disease in association with wet weather in elm spanworm larvae in Indiana. Karpel (1973) attributed the collapse of elm spanworm populations in New York to a virus epizootic. In the latter case, the elm spanworm outbreak overlapped into Connecticut in the early 1970s. We examined microscopically over 500 larvae in 1972 and 1973 and 2,000 larvae in 1971 (unpublished data), and

were unable to isolate or detect any viral infection in elm spanworm larvae. However, many larvae exhibited disease-like symptoms just before and after the larvae of the parasitoid, *A. ontario*, emerged from 4th and 5th instar hosts. Inasmuch as the causative organism was not isolated and identified and Koch's postulate not fulfilled, we don't believe the presence of viral diseases in the elm spanworm has been proven.

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A New *Otiothops* from Brazil (Araneae, Palpimanidae)

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Abstract: A new palpimanid, *Otiothops recurvus*, is described from Brazil; both the male and female genitalia are uniquely modified, and the species does not belong to any of the previously established species groups of the genus.

Through the courtesy of Dr. Charles D. Dondale of the Biosystematics Research Institute, Research Branch, Agriculture Canada, I have recently had the opportunity to examine a small collection of neotropical spiders. Included in this collection were a male and female of an undescribed *Otiothops* from Brazil; as this genus has recently been revised (Platnick, 1975) and the new species has unique genitalic modifications, an isolated description seems warranted. The extremely long embolus of the male (figs. 1, 2) resembles those of the *walckenaeri* group, but none of those species have the embolus twisted around the palpal bulb. The internal female genitalia are unlike those of any other palpimanid; instead of lying between the posterior edge of the abdominal scutum and the pedicel, the soft spermathecae are reflexed backward toward the spinnerets, and are surrounded by a leathery, striated, posteriorly invaginated mass of connective tissue that lies in a trough-like, heavily sclerotized extension of the scutum (figs. 4, 5). So far as I am aware, the hard internal extension of the abdominal scutum and posteriorly directed spermathecae are unique among spiders. The illustrations are by Dr. M. U. Shadab of the American Museum of Natural History.

Otiothops **recurvus**, n. sp.

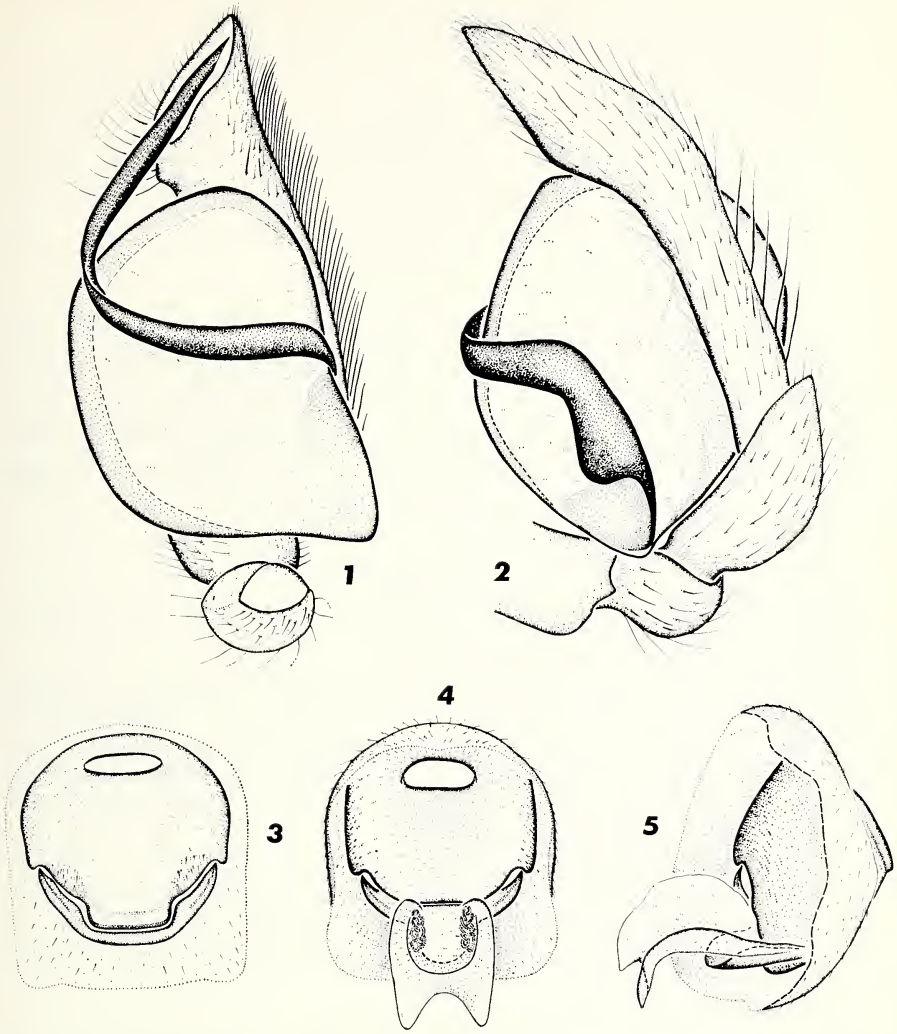
Types: Male holotype and female paratype from Cabeça do Veado, Distrito Federal, Brazil (elevation 3600 feet, October 14–November 2, 1971; E. G., I., and E. A. Munroe), deposited in the Canadian National Collection, Ottawa.

Etymology: The specific name is from the Latin *recurvus* (bent backwards) and refers to the orientation of the spermathecae.

Diagnosis: *Otiothops* **recurvus** may be easily distinguished from the other members of the genus by the elongate, twisted embolus (figs. 1, 2) and the posteriorly directed spermathecae (figs. 4, 5).

Male. Total length 4.90 mm. Carapace 2.20 mm long, 1.47 mm wide. Femur I 1.50 mm long, 0.72 mm high. Cephalic area moderately elevated. Posterior median eyes contiguous. Claw tufts present, dense. Metatarsus I with ventral series of spiniform tubercles. Embolus elongate, twisted around palpal bulb (figs. 1, 2).

Female. Total length 5.69 mm. Carapace 2.50 mm long, 1.65 mm wide. Femur I 1.58 mm long, 0.79 mm high. Somatic characters as in male. Abdominal scutum elevated medially, bordered posteriorly by sclerotized strip (fig. 3), prolonged internally into trough-like beak (fig. 5). Unsclerotized spermathecae directed posteriorly, surrounded by leathery tissue (fig. 4).



Figs. 1–5. *Otiothops* **recurvus**, n. sp. 1, ventral view of palp; 2, retrolateral view of palp; 3, ventral view of female abdominal scutum; 4, dorsal view of internal female genitalia; 5, oblique lateral view of internal female genitalia.

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A New Species of *Maladera* Mulsant (Coleoptera: Scarabaeidae: Sericinae) from India

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A survey of Haryana and some neighbouring areas for their Scarabaeid fauna revealed some new forms. The present species under genus *Maladera* Mulsant was found to be rare in occurrence though not so in distribution. Only a few specimens were collected near the light sources in two consecutive summer seasons, particularly in the months June to August. The species has been named as such after the truncate nature of the apices of elytra.

Maladera **truncatus**, n. sp.

Body short and oval, 8.0–8.5 mm long and 5.0 mm broad; orange-red to brown, with iridescent luster; head, pronotum and scutellum darker.

Head except vertex shining; clypeus strongly, coarsely and unevenly punctate, longitudinally carinate, with front margin raised and acuminate in middle. Pronotum finely and a little closely punctate. Scutellum finely and not very closely punctate. Elytra with intervals scarcely punctate in middle; apically truncate, with apical angles almost right angles and posterolateral angles obtuse. Fore tibia very strongly bidentate; claws strongly and equally cleft. Pygidium closely punctate.

Phallobase long, tubular and weakly sclerotized, with basal opening small. Parameres strongly asymmetrical, one long, strongly curved, with apex acute, other small, irregular and dilated. Endophallus elongate and sac-like. Bursa copulatrix well developed and saccular. Spermatheca long and slender; spermathecal duct opening directly into bursa copulatrix; spermathecal gland very long.

Holotype. ♂, Allotype: ♀, Kurukshetra (University Campus), Haryana, India, June 29, 1973, I. C. Mittal; deposited in the collections of Forest Research Institute, Dehradun, U.P., India.

Paratypes. 3 ♂ ♂, 1 ♀; 1 ♂, 1 ♀, data same as above, July 1973, 2 ♂ ♂, Chandigarh, India, August, 1972; 1 ♂, 1 ♀ deposited in Zoological Survey of India, Calcutta, India, 1 ♂ in National Pusa Collection, IARI, Delhi, 1 ♂, Department of Zoology, Kurukshetra University, Kurukshetra.

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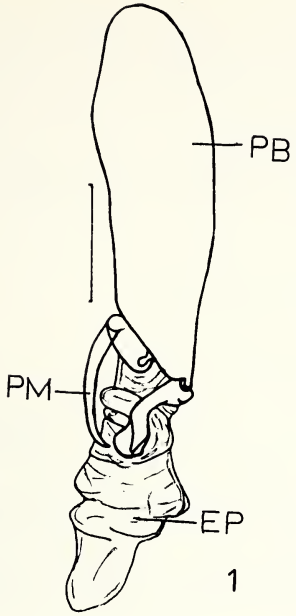

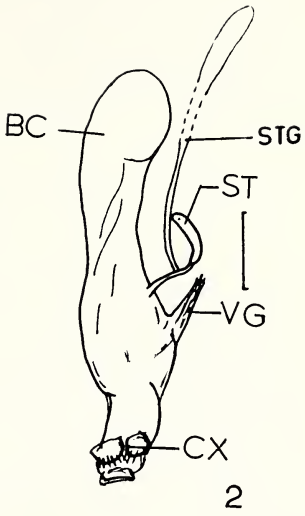

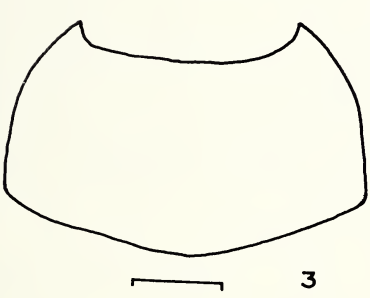

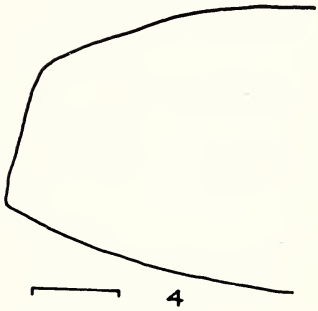

Figs. 1–4. *Maladera truncatus* sp. nov.; 1, male genitalia, dorso-lateral; 2, female genitalia, lateral; 3, thorax, dorsal; 4, hind part of left elytron. PB- phallobase, PM- parameres, EP- endophallus, BC- bursa copulatrix, ST- spermatheca, STG- spermathecal gland, VG- vagina, CX- coxites. The line of magnification in all the figures denotes 1.00 mm.

Taxonomic and Behavioral Notes on the African Ant, *Aenictus eugenii* Emery, with a Description of the Queen (Hymenoptera: Formicidae)

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Abstract: The East African army ant *Aenictus eugenii* Emery includes 1 subspecies and 3 varieties. One of these, *A. kenyensis* Santschi, is placed in synonymy, and a taxonomic history of the species is presented. The queen for the species is described for the first time and is compared with the 3 other known African *Aenictus* queens. Observations of *A. eugenii* foraging behavior show that it is a column raider and a specialized predator of ants, particularly the immature stages, that the workers move along the foraging trails in single file in small tandem groups and that they normally subdivide their prey only when it is larger than they.

Ants of the Old World genus *Aenictus* comprise the tribe Aenictini of the subfamily Dorylinae or "true army ants." The genus is represented by 34 species in the Indo-Australian region and by at least 15 species in Africa (Wilson 1964). Although Wilson (1964) taxonomically revised the genus for the Indo-Australian area, the known species in Africa are still spread among 60 nominal forms. Included in these are varietal and subspecies names that eventually must be dealt with if we are ever to appreciate the actual level of diversity achieved by this genus in Africa.

The Asian species are also better known behaviorly than their African congeners. Important biological studies of Asian species include those of Wheeler and Chapman (1925), Chapman (1964) and Schneirla and Reyes (1966, 1969). Biological observations of sub-Saharan species are limited to a recent study by Gotwald (1975) and to fragmentary reports by Brauns (1901), Arnold (1915), and Sudd (1959). Some biological information on African species can be gleaned from the original species descriptions, but much of the information is little more than anecdotal.

Acknowledgments: We are grateful to Dr. William L. Brown, Jr., Cornell University, for critically reading the manuscript. We also thank Dr. David H. Kistner, California State University, Chico, for kindly providing essential specimens and for identifying one of the myrmecophiles. The research was supported by National Science Foundation Grants GB-22856 and GB-39874 (W. H. Gotwald, Jr., Principal Investigator).

Aenictus eugenii Emery is distributed throughout much of East Africa, although it is not frequently seen. During the past 4 years we have encountered the species only 6 times, but on 4 of these occasions, we were able to observe, to some extent, the behavior of the species. Dr. David H. Kistner, California State University, Chico, has kindly provided us with a series of workers and an associated queen of the species, and we are now able to describe the queen for the first time. We have also provided a taxonomic history of the species including a new synonym.

TAXONOMY OF THE SPECIES

Aenictus eugenii

Aenictus eugenii Emery, 1895, Ann. Soc. Entomol. Fr. 63: 17–18, worker. Type locality Makapan (Transvaal, South Africa). Types in the Museo Civico di Storia Naturale, Genoa, examined 1972.

Aenictus eugenii var. *kenyensis* Santschi, 1933, Bull. Ann. Soc. Entomol. Belg. 73: 100, worker. Type locality "Kiambou," Kenya. Cotypes in the British Museum (Natural History), London, examined 1972. New Synonymy.

Subsequent to Emery's description of *A. eugenii*, Santschi described for the species 3 varieties that he called *brazzai* (1910), *henrii* (1924), and *kenyensis* (1933), and Forel (1910) described one subspecies named *caroli*. In 1924, Santschi elevated *brazzai* to specific rank because it lacked the conspicuous clypeal teeth common to *eugenii*. Santschi (1924) described *henrii* as intermediate between *caroli* and the *eugenii* type specimens and based his description on the shape of the head and disposition of the clypeal teeth. His short description of *kenyensis* (1933), on the other hand, relied heavily on differences in overall coloration and on the length of the antennal scape, which he perceived as shorter than that of Emery's types. We have examined the type specimens of *eugenii* and *kenyensis* and cannot justify the existence of the latter as distinct within the species *eugenii*. Although the *kenyensis* type specimens are smaller than those of *eugenii*, they are alike in other respects.

We have also examined cotypes of *caroli* but are not prepared to deal with its status until types of other East African species are examined. This subspecies is small and equal in size to the smallest *eugenii* specimens that we examined from Kenya. While its pattern of punctation is like that of *eugenii*, it is entirely golden-yellow (the head and alitrunk of *eugenii* are reddish-brown).

The specimens of *eugenii* that we examined, excluding *caroli*, ranged in total length from 4.20 mm for specimens from Rhodesia to 3.51 mm for specimens from Kenya. Preliminary measurements suggest that worker size varies clinally with the largest workers representing the southern end of the cline.

Queen Description: Total length 10.55 mm, head length 1.53 mm, head width 1.62 mm, cephalic index 106, alitrunk length 2.20 mm, petiole length 0.72 mm, gaster length 6.10 mm, scape length 0.72 mm, length of petiolar node 0.67 mm, width of petiolar node 0.90 mm, hind femur length 1.35 mm, mandible length (from point of insertion to tip of apical tooth) 0.81 mm.

Habitus as in Figs. 1A and 1B. Head, alitrunk, petiole, gaster and appendages reddish-brown. Darkest on mandibles and dorsum and venter of gaster.

Head as in Fig. 1E. Head sutureless, without eyes, punctation or frontal carinae. Occipital margin (as in Fig. 1E) medially concave. Antennal fossae deeply impressed.

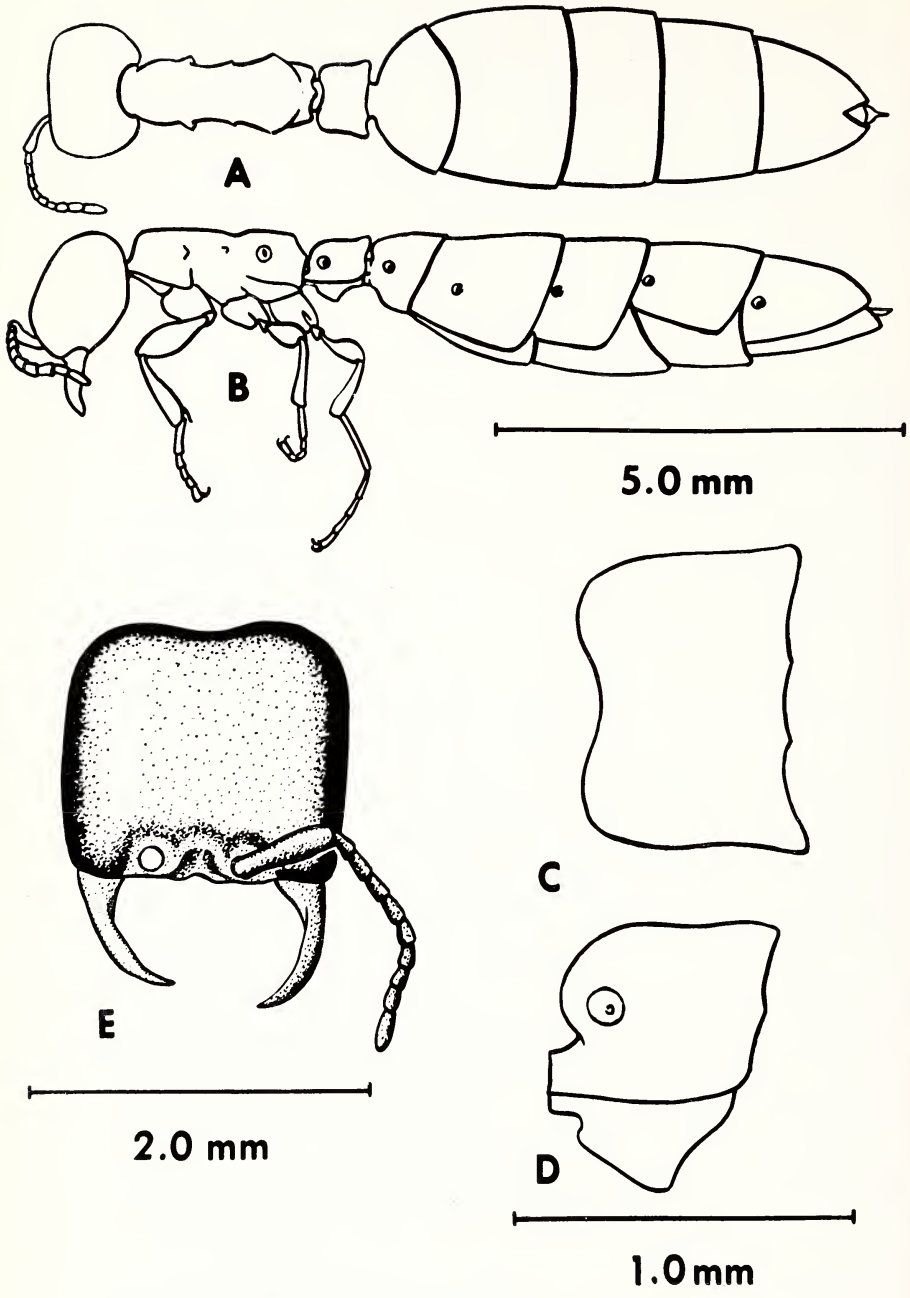

FIG. 1. External morphology of the queen of *Aenictus eugenii*, pilosity omitted. (A) General habitus, dorsal aspect; (B) general habitus, lateral aspect; (C) petiolar node, dorsal aspect; (D) petiolar node, lateral aspect; (E) head, dorsal aspect.

Clypeus medially emarginate, without teeth or other distinguishing characteristics. Antenna 10-segmented; scape short.

Alitrunk as in Figs. 1A and 1B. Alitrunk without conspicuous sutures or punctation. Meso- and metathoracic spiracles form raised, tubercle-like structures; propodeal spiracle conspicuous but not elevated. Distal margin of bulla covering metapleural gland orifice conspicuous, parallel to the longitudinal axis of the body and located directly beneath the propodeal spiracle. Declivity of the propodeum slightly concave.

Petiolar node as in Figs. 1C and 1D. Posterior lateral angles prominent; posterior third of petiolar dorsum smoothly concave between angles. Anterior margin of node, in dorsal view, concave. Subpetiolar process prominent, triangular, and directed caudally.

Gaster as in Figs. 1A and 1B. Integument of gaster without conspicuous punctation. Gaster with 5 visible segments; tergite of 5th segment deeply notched medially along the posterior margin. Tip of ovipositor (?) conspicuous.

Entire body shiny, without conspicuous punctation. Pubescence yellow, sparse, and most conspicuous in small patches on anterolateral angles of head, the mandibles, antennae, legs, and posterior margins of gastral sclerites; groups of setae elsewhere on pronotum, propodeum and petiole. Tarsal claws simple.

The queen was collected with a series of workers at Kundulungu, "Congo Republic," 20 March 1950, by N. Leleup. The queen, together with the workers, is deposited in the Musée Royal de l'Afrique Centrale, Tervuren, Belgium.

Each *Aenictus* species contains multiple phena (i.e. queens, workers, and males) and the correlation of these phena for any one species, unless found together in the same colony, is impossible. Because the males are common at light but seldom found with their colonies, a complicated synonymy exists. Wheeler (1930) pointed out that of the *Aenictus* species known in 1930, 28 were known from workers only, 48 from males only, 3 from males and workers only, and 1 from workers and females only. Associated phena must be found and described in order to solve this synonymic tangle.

Until 1930, only 3 *Aenictus* females or queens had been described, and all 3 were collected in Africa. The first *Aenictus* queen to be characterized was taken by André (1885) to be a doryline worker, which he named *Alaopone abeillei*. This "worker" was recognized to be a queen and placed in the genus *Aenictus* by Emery (1901), but the species rests solely on the single unassociated female originally described by André. The second African female described, *A. vaucheri* Emery (1914), also remains unassociated. However, the third queen to be characterized was taken with a series of previously described workers belonging to *A. congolensis* Santschi. This queen was described by Santschi (1917). The queens of *A. abeillei* and *A. vaucheri* were collected in northern Africa (Oran and Morocco respectively) while *A. congolensis* was taken at Lambarené, Gabon. The first *Aenictus* females from the Indo-Australian region were described by Wheeler (1930). Both, *A. martini* (= *gracilis* Emery) and *A. laeviceps* (Fr. Smith), were from the Philippines. The queen of *A. eugenii* is the fourth African *Aenictus* female described and only the second from subsaharan Africa.

The 4 described African queens range in total length from 8 mm (*abeillei*) to 14 mm (*congolensis*); all possess 10-segmented antennae, thoracic suturing is greatly reduced or absent, and they are either reddish-yellow (*abeillei*) or reddish-brown (*vaucheri*, *congolensis*, *eugenii*). The queen of *eugenii* is unique among the 4 in possessing the notched 5th gastral tergite. Although this notch is symmetrical and medial in location, it may be the result of injury to the queen. The African *Aenictus* queens are similar to one another and appear closely related. Females of Asian species, on the other hand, differ from the African forms in a significant number of details, and these differences prompted Wheeler (1930) to suggest "that they would seem to belong to a distinct genus. . . ." These differences are obvious in overall body shape and structure, and *A. laeviceps* even possesses a "minute ocellus in the

frontal groove" (Wheeler 1930). Other Indo-Australian queens now known include *A. aratus* Forel, *A. binghami* Forel, *A. ceylonicus* (Mayr), and *A. currax* Emery, and these queens exhibit complex variation (Wilson 1964). In general, the African females have a simplified, reduced structure, particularly in the head and thorax, where few sutures or sclerites are evident. The subpetiolar process is the only exception, since it is well-developed in the African forms and virtually absent in the Indo-Australian queens.

The female functional reproductive cycle in African species is not known. Of the 4 queens, only the *A. congolensis* specimen was physogastric, indicating that it was gravid at the time of its capture. The intersegmental membranes of this specimen were greatly stretched and the sclerites widely sparated (Santschi 1917). The other queen specimens, including *A. eugenii*, have unexpanded gasters that suggest a non-gravid phase for each.

BEHAVIOR OF THE SPECIES

The primary extra-nidal activities in which *Aenictus* workers are involved are foraging and colony emigration, but this investigation is restricted to foraging behavior. Observations of *A. eugenii* colonies were limited to columns of worker ants traveling to or from their nests, usually discovered crossing footpaths where the hard-packed soil and absence of litter forced their exposure. The 4 colonies studied were observed at Karen (nr. Nairobi), Kenya and were designated: KC-081 (26 July 1971), KC-111 (4 May 1972), KC-112 (19 Sept. 1972), and KC-113 (28 March 1973). All columns were presumed to be foraging, either because the workers carried prey or because in the absence of prey they were not engaged in carrying their own brood.

Workers of colony KC-081 (discovered at 0930 hrs) moved along several anastomosing trails in tandem groups of 2 to 10 or more individuals. The workers moved in single file, and the tandem groups on any one trail were often widely separated from one another. Because different groups used the same trails at different times, it was obvious that the trails were chemical.

Colony KC-111 was detected as a foraging column, several meters in length, raiding the nest of an ant of the genus *Pheidole*. Several small columns branched from the main trunk, and some of the *Aenictus* workers encountered termite workers, which they ignored. A single myrmecophile was collected and was tentatively identified as *Aenigmatopoeus sequax* Borgmeier, a phorid fly that is also a predator of the driver ant *Dorylus* (*Anomma*) *nigricans* var. *molestus* (Gerstaecker) (Kistner, personal communication).

Colony KC-112 was initially discovered at 0800 hrs (sky overcast, temperature 15.6°C) as a series of columns crossing a footpath and entering a flower garden. These columns branched from a base column of workers moving in single file, about 2 m long, that issued from a hole in the soil. At the end of each branch column, workers gathered, sometimes numbering in the hundreds, and proceeded to search an area approximately 30 cm square. The foraging workers moved swiftly in their search activity, and numerous workers returned along the original trail without evidence of booty. There were 5 to 7 such foraging groups which returned to the main column following completion of their

search. The foraging activities of the column continued until 1200 hrs. One raiding group attacked a nest of *Pheidole megacephala* (Fabricius), and although they attacked individual *Pheidole* workers none were killed or taken as prey. One branch column of returning workers carried booty consisting of ant brood that was brought up from a hole in the soil, presumably the opening to the prey species nest. Of the 13 prey individuals taken from the foragers, 12 were pupae, 1 was a larva, and all were equal in size to the foraging workers. The prey species belonged to the subfamily Myrmicinae (probably *Pheidole*). *Bengalia* flies gathered about the raiding groups and occasionally stole prey from the *Aenictus* workers. The main column could not be traced back to the nest.

Colony KC-113 was discovered at 0830 hrs as a main foraging column returning to the nest with booty. At 1030 hrs it was still moving large numbers of prey. Curiously, this column was traveling on a well-worn trail of *D.* (*A.*) *nigricans* var. *molesta*, and in fact, it passed directly over the active nest of this driver ant without conflict. Of the 286 prey units (whole individuals and/or pieces of individuals) collected from the returning foragers, all were ants or the subfamily Myrmicinae and all were imature forms. The prey units consisted of 101 whole larvae, 165 whole pupae, 7 pupal heads, 10 pupal gasters, 1 pupal alitrunk, and 2 pupae without heads. Of the 20 prey units that were pieces of pupae, 17 were from individuals that were obviously much larger than the *Aenictus* workers.

The foraging behavior of *A. eugenii* is like that of the West African species observed by Sudd (1959) and Gotwald (1975). The similarities are as follows: (1) workers commonly move in single file in small groups along the foraging trails; (2) *A. eugenii* is a specialized predator of ants, especially on the immature stages of ants of the subfamily Myrmicinae; (3) this species is a column raider, i.e. the terminal branches of a main foraging column each end in a small group of workers that search for and capture prey in a relatively small area; and (4) the foraging workers do not subdivide their prey before retrieval unless the prey individuals are larger than the foragers themselves. Only 2 behavioral observations on *A. eugenii* appear in the literature. Arnold (1915) observed a group of workers "marching in single file and carring larvae from under one large stone to another" (although he failed to identify the column as foraging or emigrating), and Santschi (1933) noted that his type series for *kenyensis* was attending a species of *Pseudococcus*. This latter observation implies that these workers were collecting honeydew, a behavior pattern recorded only once before for doryline ants (Arnold 1915).

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Terrestrial Mites of New York (Acarina). IV. Cheyletidae and Cheyletiellidae[1]

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Abstract: Ten species of Cheyletidae and 3 species of Cheyletiellidae are presently known from New York. New records of *Acaropsis sollers* Rodendorf, *Cheletomorpha lepidopterorum* (Shaw), *Cheyletus hendersoni* Baker, *C. fortis* Oudemans, *Eucheyletia bishoppi* Baker, *Hemicheyletia wellsi* (Baker), *Neochelacheles messersmithi* Smiley & Williams, and *Prosocheyla oaklandia* (Baker) are listed here. Two species are described as new: *Eucheyletia* **nidicola**, and *Hemicheyletia* **newyorkensis**. Diagnostic features, as well as distributional and biological information are given for most species.

This paper is the fourth in a series devoted to a taxonomic survey of terrestrial mites of New York. It reports 10 species of Cheyletidae, of which 2 species are described as new, and 3 species of Cheyletiellidae formerly placed in Cheyletidae. The latter species have been previously reported from New York; they are included here to call attention to their increasing public health significance. They are parasitic, and cause dermatitis in man, and mange in cats, dogs, rabbits and foxes (Olsen & Roth, 1947; Taylor, 1969; Smiley, 1965 & 1970; Hewitt, et al., 1971; van Brunswijk, et al., 1972; Bjarke, et al., 1973; Keh, 1975). The family Cheyletidae includes many species of free-living predaceous mites of economic importance. They have been collected in many habitats such as skins and nests of birds and mammals, insect nests, plants and dried plant material, granaries and barns, and in association with bark beetles and scale insects. Several species have been commonly found in stored food products which are infested by astigmatid mites, upon which the cheyletids prey. They are considered to be effective in controlling stored food product mite populations.

The cheyletids in this report were collected from various habitats in central and eastern New York. The systematics of Cheyletidae follows that of Summers & Price (1970), and Cheyletiellidae that of Smiley (1970).

We thank Dr. E. W. Baker, U.S. Department of Agriculture, for his help in checking the specimens and in making the illustrations, and Mr. B. M. O'Connor, Cornell University, for providing us with additional specimens.

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Family CHEYLETIDAE

Acaropsis sollers Rodendorf

Acaropsis sollers Rodendorf, 1940, Wiss. Ber. mosk. Staats Univ. Zool. 42: 78, 79. Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 61.

The specimens from New York which we have identified as *sollers* seem to fit the description and figures of *docta* (Berlese) as given by Baker (1949). The 2 species may be separated by the length of the dorsal seta on palpal femur, longer than femoral segment in *sollers*, shorter than femoral segment in *docta* (see Summers & Price, 1970: 61).

Distribution: *A. sollers* was previously known only from the type-locality, Leningrad, U.S.S.R.; it was subsequently found in California. Four females were collected from a bird nest, Farmingdale, Long Island, New York, December 12, 1975, by M. J. Abbatiello. This is a new record for New York.

Cheletomorpha lepidopterorum (Shaw)

Acarus lepidopterorum Shaw, 1794, Nat. Misc. 6, pl. 187.
Cheletomorpha lepidopterorum, Baker, 1949, Proc. U.S. Nat. Mus. 99: 302. Summers & Price, 1970. Univ. Calif. Publ. Entomol. 61: 49.

This is a long-legged mite with long body and leg setae which are rodlike-serrate and slightly flattened on the end; the tarsus of leg I lacks claws but has a pulvillus; the dorsomedian setae are very small and well differentiated from the dorsolateral setae, 2 pairs on the propodosomal plate and 2–3 pairs on the hysterosomal plate. The female palpal claw is long and slender, and has 1 tooth; that of the male has 2–3 smaller teeth. According to Summers & Price (1970), *lepidopterorum* is a variable species and variants may have been misidentified.

Distribution: *C. lepidopterorum* is a widely distributed mite, being found on various importations from all parts of the world. One female was found on underside of a shrub leaf, east Ithaca, New York, September 19, 1970, by B. M. OConnor. It is the first for New York. Also, 1 female and 1 immature were taken from wild oats-bunny tail packing material from Italy at Copiague, Long Island, August 27, 1975, by M. J. Abbatiello.

Cheyletus hendersoni Baker

Cheyletus hendersoni Baker, 1949, Proc. U.S. Nat. Mus. 99: 279. Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 29.

C. hendersoni resembles *trouessarti* Oudemans in many respects, including 3 pairs of small vesicular dorsomedian setae, 1 pair on the propodosomal plate and 2 pairs on the hysterosomal plate. But *hendersoni* is distinctive in having some of the serrate dorsolateral setae long and flagelliform; in *trouessarti* these setae are flattened, spindle-shaped blades with fine barbs. There are only 3 teeth on the palpal claw, and the guard seta on tarsus I is longer than the solenidion.

Distribution: Arkansas (type-locality), New Mexico and Colorado. The 4 females collected in New York were from a woodchuck nest, Saratoga, September 9, 1975, by M. D. Delfinado. This is a new record for New York.

Cheyletus eruditus (Schrank)

Acarus eruditus Schrank, 1781, Enumeratio insectorum Austriae indigenorum: 513.
Cheyletus eruditus, Baker, 1949, Proc. U.S. Nat. Mus. 99: 278. Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 24.

C. eruditus is closely related to *malaccensis* Oudemans, but differs by having 2 similarly developed basal teeth on the palpal claw and 2 setae on the femur of leg IV. *C. malaccensis* has 2 different sized teeth and 1 seta on the femur of leg IV.

Distribution: This species is widely distributed. It has been recorded from New York, and described as *Cheyletus doddi* Baker, 1949: 279 from Ithaca. New collections of several males, females and immatures were found in pigeon dung, Farmingdale, Long Island, July 1973; barn debris, Bethlehem, Rt. 144, Albany County, July 2, 1974; ant nest debris, Saratoga, August 29, 1975, all collected by M. D. Delfinado; from wild oats-bunny tail packing material from Italy at Copiague, Long Island, August 27, 1975, collected by M. J. Abbatiello.

Cheyletus fortis Oudemans

Cheletes fortis Oudemans, 1904, Entomol. Ber. 18: 160.
Cheyletus fortis, Baker, 1949, Proc. U.S. Nat. Mus. 99: 280. Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 28.

C. fortis is difficult to separate from *malaccensis*. The females of *fortis* are distinguished by having one large blunt tooth on the palpal claw; *malaccensis* has a similar large tooth and a small, secondary tooth. The males differ in the number of dorsolateral hysterosomal setae, 5 pairs in *fortis* and 6 pairs in *malaccensis*.

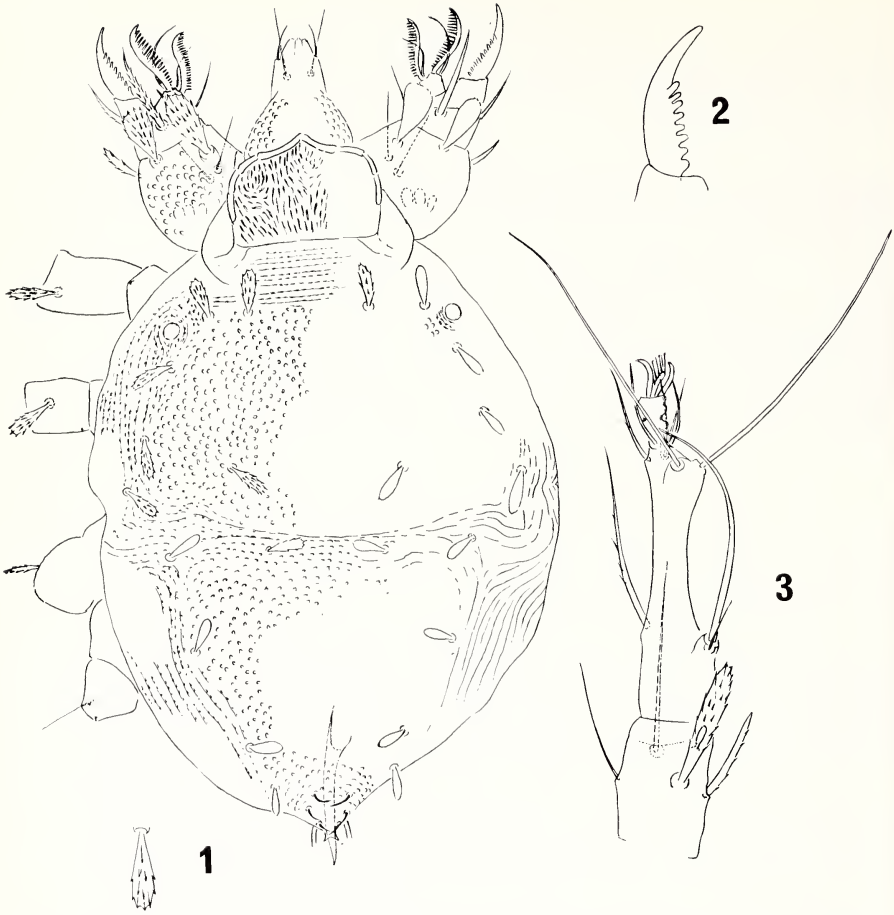
Distribution: This species has been intercepted at U.S. Quarantine on many host habitats from Southeast Asia, Japan and Australia. The 2 specimens from New York were collected on a dead adult mealworm from a laboratory culture at Cornell University, Ithaca, March 1969, by Steve Gourley. This is also the first record for North America.

Eucheyletia bishoppi Baker

Eucheyletia bishoppi Baker, 1949, Proc. U.S. Nat. Mus. 99: 295. Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 32.

This species has characters typical of the genus, including the presence of cloudlike setae, and the absence of lenslike eyes. *E. bishoppi* may be recognized from its closely related species, *flabellifera* (Michael), in having palmate-serrate ventral seta of the palpal genu, 5–6 pairs of palmate-serrate dorsolateral and 7–8 pairs of cloudlike dorsomedian setae on the hysterosomal plate, and in having lanceolate-serrate ventral seta on tibia III. *E. asiatica* Volgin is possibly a synonym of *bishoppi*; Summers & Price (1970) separate the 2 species only by the number of cloudlike setae: 7 pairs in *bishoppi* and 8 pairs in *asiatica*. The specimens of *bishoppi* we have examined possess 7–8 pairs of cloudlike setae.

Distribution: This mite has been collected in Maryland and California (type-locality). Two females were collected from Tompkins County, New York, March 27, 1975, from nest of *Blarina brevicauda* (Say), by B. M. OConnor; a new record for the State.



Hemicheyletia newyorkensis, n. sp. Figures 1–3. 1, dorsal view of male with detail of seta; 2, palpal claw; 3, tibia-tarsus of leg I.

Hemicheyletia **newyorkensis**, n. sp.

(Figures 1–3)

This new species, described from a male, exhibits the *bakeri* type of body setae, the dorsomedian setae being similar in form with the dorsolateral setae. *H.* **newyorkensis** is distinctive in having the hysterosomal and propodosomal plates being well developed and about equal in size, with similarly narrow clavate-serrate dorsomedian and dorsolateral setae; each plate bears 1 pair of dorsomedian and 4 pairs of dorsolateral setae.

Male. Body ovoid, length 287 u, width 166 u. Palpal claw with 8 small, similarly shaped teeth. Outer comb with about 16 teeth, and about as long as palpal claw. Inner comb smaller than outer comb, with about 19 teeth. Palpal femur slightly wider than long, with palmate-serrate dorsal seta. Palpal genu with palmate-serrate seta located along posterior

margin. Tip of rostrum more or less conical, with well developed marginal lamellae. Protegmen covered with small tubercles. Peritremes with 4 or 5 sausage-like links on each side. Tegmen with many longitudinal striae at base breaking into shorter striae anteriorly. Entire body covered by 2 well developed dorsal plates, about equal in size. Dorsal integument covered with tiny tubercles arranged in rows, with tuberculate striae surrounding propodosomal and hysterosomal plates. Lenslike eyes prominent, surrounded by striae. All dorsal setae narrow clavate-serrate. Each plate with 1 pair of dorsomedian and 4 pairs of dorsolateral setae. Dorsomedian and dorsolateral setae in size and shape. Genital-anal setae simple and smooth. Tibia-tarsus of leg I as in figure 3. Solenidion on tarsus I very long, borne on tubercle; guard seta very small.

Female. Not known.

Holotype. Male, unique, Flanders, Long Island, New York, July 16, 1973, from leaf litter near base of tree, collected by M. D. Delfinado. Deposited in the New York State Museum & Science Service at Albany.

Hemicheyletia wellsi (Baker)

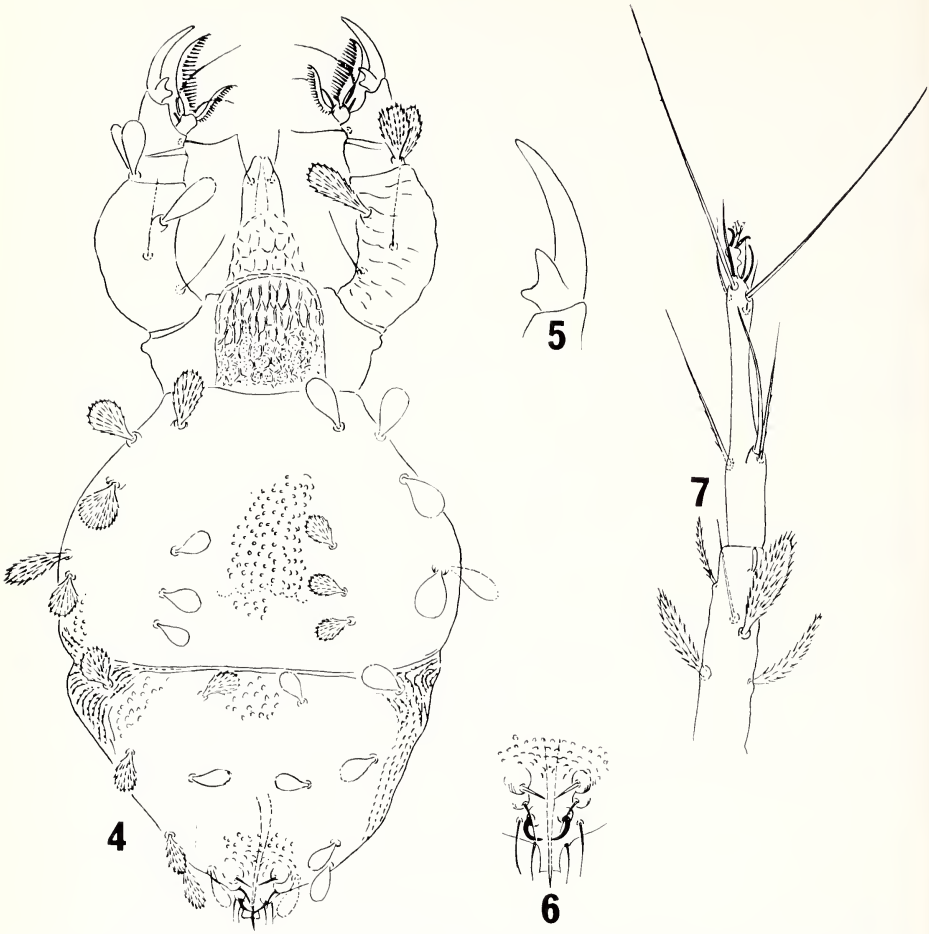
Cheyletia wellsi Baker, 1949, Proc. U.S. Nat. Mus. 99: 300.
Hemicheyletia wellsi, Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 15.

H. wellsi is recognized by having the dorsomedian setae aberrant or fragmented, very different from the dorsolateral setae; the hysterosomal plate bears 2 pairs of fragmented dorsomedian setae, and the propodosomal plate bears 3 or 4 pairs of similar setae.
Distribution: Azores (type-locality), Puerto Rico, Mexico, Hawaii, West Indies, Cuba, Jamaica, Okinawa, Argentina, Chile and Panama. The 2 specimens in our collection were from treehole debris, Forest Park, Queens, New York, June 1973, collected by M. D. Delfinado. This is also first record for North America.

Eucheyletia **nidicola**, n. sp.
(Figures 4–7)

This species, based only on the male, markedly differs from other members of the genus by the type of the dorsomedian setae: these are palmate-serrate instead of cloudlike, 3 pairs on the propodosomal plate and 2 pairs on the hysterosomal plate; it has 2 large basal teeth on the palpal claw and palmate-serrate ventral seta on the palpal genu.

Male. Body elongate ovoid, length including rostrum, 447 u, width 249 u. Palpal claw with 2 large basal teeth. Outer comb with about 16 teeth. Inner comb with about 30 teeth, as long as palpal claw. Palpal femur curved, longer than wide, with palmate-serrate dorsal seta. Palpal genu with palmate-serrate setae. Rostrum and protegmen both elongate and conical, with rostrum protruding. Protegmen with reticulate pattern of ridges. Tegmen also with similar pattern except reticulum broadly elongate anteriorly. Peritremes with 7 or 8 small links on each side. Lenslike eyes lacking. Dorsal integument covered with small tubercles arranged in rows; striae surrounding dorsal plates and between legs formed like tubercles. Propodosomal and hysterosomal plates located close together. Propodosomal plate slightly larger than hysterosomal plate, with 7 pairs of dorsal setae, 3 pairs dorsomedian. Hysterosomal plate also with 7 pairs of dorsal setae, 2 pairs



Eucheyletia nidicola, n. sp. Figures 4–7. 4, dorsal view of male; 5, detail of palpal claw; 6, detail of genitalia; 7, tibia-tarsus of leg I.

dorsomedian. Altogether 14 pairs of dorsal setae including humeral setae present. All dorsal setae broadly palmate-serrate, with dorsolateral setae noticeably larger than dorsomedian setae. Genital-anal setae simple and smooth, 1 pair strong and clawlike. Solenidion on tarsus I fairly long; guard setae about as long as solenidion. Tibia-tarsus setae of leg I as figured.

Female. Unknown.

Holotype. Male, unique, Newcomb, Adirondacks Mts., New York, August 8, 1973, collected from unidentified mammal nest, by M. D. Delfinado. Deposited in the New York State Museum & Science Service collection at Albany.

Neochelacheles messersmithi Smiley & Williams

Neochelacheles messersmithi Smiley & Williams, 1972, Proc. Entomol. Soc. Wash. 74: 312.

N. messersmithi, the only species presently included in the genus, is easily recognized by the long and slender body with 2 dorsal plates marked with elongate ridges or alveoli, each plate bearing 6 pairs of large clavate-serrate setae. The palpal tarsus has 1 comblike and 2 sicklelike setae, and the palpal claw has 5 pointed teeth. The male is not known.

Distribution: This mite was originally found on *Bolitotherus cornutus* (Panzer) from West Virginia. Five females were also found on *B. cornutus*, Ithaca, June 1973 & Schuyler County, New York, September 1975, by B. M. OConnor, and 1 female on fungus, Rensselaerville, New York, by M. D. Delfinado. This is a new record for New York.

Prosocheyla oaklandia (Baker)

Cheletogenes oaklandia Baker, 1949, Proc. U.S. Nat. Mus. 99: 306.
Prosocheyla oaklandia, Summers & Price, 1970, Univ. Calif. Publ. Entomol. 61: 55.

P. oaklandia has the identifying features of the genus: tarsus I lacks pretarsus and pedicel, and the hysterosoma possesses 1 large plate covering most of the metapodosoma and the opisthosoma. The similarly palmate-serrate dorsomedian and dorsolateral setae readily separates *oaklandia* from other species in the genus. The male palpal femur is considerably longer that of the female and bears a strong spine on its dorsal surface which resembles the palpal claw.

Distribution: This species was previously known only from California (type-locality). Two males were collected from roots and debris, Jones Beach, Long Island, New York, June 1973, by M. D. Delfinado. A new record for the State.

Family CHEYLETIELLIDAE

Mites of the family Cheyletiellidae are all parasitic of mammals and birds. Three species of *Cheyletiella*, the only genus in the family that is connected with human skin disease, are known to occur in New York. These are:

Cheyletiella blakei Smiley, 1970, Ann. Entomol. Soc. Amer. 63: 1072.

This species was collected from cat hair at Ithaca (type-locality); it was recently reported in California causing dermatitis in man which was traced to an infestation of the mite on cats (Keh, 1975).

Cheyletiella parasitivorax (Megnin), Baker, 1949, Proc. U.S. Nat. Mus. 99: 270. Smiley, 1970, Ann. Entomol. Soc. Amer. 63: 1075.

This is a cosmopolitan species found on rabbits. The New York records are from Albany and Ithaca.

Cheyletiella yasguri Smiley, 1965, Proc. Entomol. Soc. Wash. 67: 76; 1970, Ann. Entomol. Soc. Amer. 63: 1072.

This species has been reported causing dermatitis on dogs (Smiley, 1965; Ewing, et al., 1967; Hewitt, et al., 1971) and as a hyperparasite of a hippoboscid fly (Vercammen-

Grandjean & Rak, 1968). In 1972 van Brunswijk, et al. reported high infestation of *yasguri* in a house where a person complained of severe itching. A dog was the source of the infestation. The New York records are from Mamaroneck (type-locality) and Ithaca, taken from dogs.

The 3 species can be easily separated in both sexes by the shape of the sensory seta of genu I, and by the shape of the aedeagus in the male (Smiley, 1970). We have not studied any of these species.

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Third Addition to the Supplemental List of Macrolepidoptera of New Jersey

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Received for Publication February 9, 1976

Abstract: In this list 43 species, subspecies and named aberrations with larval hostplant, where known, are added to the Supplemental List of Macrolepidoptera of New Jersey, 1965.

Saturniids sphingids, *Catocala* and some species of butterflies are scarcer than ever in the Lebanon area for no explainable reason. Therefore most of my collecting was done in south New Jersey. Thanks to the help of lepidopterist friends these new records for the state have been possible. I want to thank especially Dr. C. B. Worth who is so kind as to let me use his 178 acre farm located at Eldora, Cape May Co., where I put up several black lights and bait traps. His farm consists of extensive woods, field, orchard and flower garden. He also collects for me when I am not there myself. I am also grateful to Dr. J. P. Reed of Rutgers College of Agriculture, who gave me rare records of specimens collected in light traps in south New Jersey.

Again checklist numbers and classification for moths are taken from McDunnough, 1938. Checklist numbers for butterflies follow dos Passos (1964–70). Specimens not followed by the name of a collector were caught by the author. All specimens from Eldora were caught by the author with the collaboration of Dr. Worth.

BUTTERFLIES

Papilionidae

Papilio Linnaeus

248 *polixenes* Fabricius; ab. "calverleyi" Grote. Toms River, June 10. Lemmer. General feeder on Umbelliferae.

Nyphalidae

Melitaea Bates

592 *phaeton* Drury; ab. "phaethusa" Hulst. Johnsonburg, July 14. Adelberg. *Chelone glabra.*

Acknowledgments: Thanks to Dr. F. Rindge, Dr. A. E. Brower, and Eric Quinter for determining some of the following species.

MOTHS

Sphingidae

Pholus Hübner
776 *fasciatus* Sulzer; Lebanon, Sept. 7. New Egypt, Sept. 3. Rutgers.

Nolidae

Sarbena Walker
897–1 species according to Forbes. Lebanon, June 11. Eldora, June 4.

Arctiidae

Crambidia Packard
908 *uniformis* Dyar; Seabrook, June 26. Rutgers.

Cisthene Walker
934 *tenuifascia* Harvey; Eldora, June 5.
936 *unifascia* Barnes & Benjamin; a *kentuckiensis* Dyar. Cedarville, July 8. Rutgers.
941 *injecta* Dyar; Eldora, June 5.

Ecpantheria Hübner
1085 *deflorata* Fabricius; a *denudata* Slosson. Short Hills, Aug. 3. Low plants.
form *confluens* Oberthur; Lebanon, June 26.

Phalaenidae (Noctuidae)

Acronicta Ochsenheimer
1180 *spinigera* Guenée; Lebanon, June 8, Sept. 17.

1184 *pruni* Harrison
form *prunata* Barnes & Benjamin; Lebanon, May 19, Short Hills, July 29. On apple.

Hadeninae

Meliana Curtis
1968 *flabilis* Grote; Eldora, June 22.
1970 *linita* Guenee; Thorofare, July 10. Rutgers.

Leucania Ochsenheimer
1996 *rubripallens* Smith; Martinsville, March 31. Rutgers.
1998 *oxygala* Grote; Hazlet, June 6. Rutgers.

Cuculiinae

Cucullia Schrank
2036 *alfarata* Strecker; Eldora, Aug. 16. Aster.

Graptolitha Hübner
2234 *baileyi* Grote; Lakehurst, Oct. 16. Cadbury III. Choke Cherry.

Amphipyrinae

Luperina Boisduval
2387 *stipata* Morrison; Eldora, July 23. Stalk borer.

Oligia Hübner
2412–1 *crytora* Franclemont; Short Hills, June 19.

Spartiniphaga McDunnough
2436 *inops* Grote; Batsto, Sept. 22. Schweitzer. Larva in *Spartina*.

Hypocoena Hampson
2448 *inquinata* Guenée; Columbia, July 17. Rutgers.

Elaphria Hübner
2643 *nucicolora* Guenée; Batsto, Nov. 10. Carter & Schweitzer.

Prodenia Guenée
2681 *eridana* Cramer; Eldora, Nov. 6.

Stibadium Grote
2779 *spumosum* Grote; Delanco, July 28. Thorofare, July 30. Rutgers. No locality or date in Smith's list.

Heliothiinae

Heliothis Ochsenheimer
2927 *lupata* Grote; Indian Mills, Aug. 14. Thorofare, Aug. 10. Rutgers. Grasses.
2929 *paradoxa* Grote; Masonville, July 5. Rutgers.

Catocalinae

Zale Hübner
3492 *bethunei* Smith; Lebanon, July 17. Scrub pine, *Pinus virginiana*.
3494–1 *confusa* McDunnough; Batsto, April 5, May 11. Schweitzer. Probobly *Pinus echinata*.

Melipotis Hübner
3549 *indomita* Walker; Adelphia, June 30. Rutgers. Mesquite.

Metalectra Hübner
3655 *diabolica* Barnes & Benjamin; Lakehurst, Aug. 18.

Herminiinae

Camptylochila Stephens
3725 *aemula* Hübner; ab. "herminoides" Walker. Lebanon, Oct. 13.

Xylormisa Forbes
3777 *louisiana* Forbes; Eldora, Aug. 5.

Hyblaeinae

Hyblaea Fabricius
3814 *puera* Cramer; Eagerstown, Sept. 31. Rutgers.

Lasiocampidae

Epicnaptera Rambur
3999 *americana* Harris; form *ferruginea* Packard. Montague, July 13. Apple, birch, poplar.

Zanolidae (Eupterotidae)

Apatelodes Packard

4001 *torrefacta* Abbot & Smith; a *floridana* Hy. Edwards. Masonville, July 5. Rutgers.

Geometridae

Sterrhinae

Sterrha Hübner

4192 *punctofimbriata* Packard; Eldora, July 17.

Larentiinae

Eupithecia Curtis

4287 *palpata* Packard; Lebanon, May 8. Pine and spruce.

Ennominae

Hesperumia Packard

4801 *sulphuraria* Packard; form *baltearia* Hulst. Montague, July 22. *Ceanothus*, also Snowberry.

Anacamptodes McDunnough

4915 *defectaria* Guenée; Eldora, Dec. 4. Poplar, willow.

Hulstina Dyar

4932 *inconspicua* Hulst; Lebanon, March 24.

Metarranthis Warren

5050 *duaria* Guenée; form *hamaria* Guenée. Eldora, June 22. Wild Cherry, blueberry.

Apicia Guenee

5180 *fundaria* Guenée; Eldora, Oct. 27.

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Modern Type Concepts in Entomology

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Received for Publication February 27, 1976

Abstract: Twenty-six new type concepts are proposed to alleviate the barrenness of current type methodology. The proposed type concepts are commonly used and practiced but completely unrecognized in the scientific literature. The truth inherent in these new proposals will be patently evident and should be given due consideration in light of current systematic procedures.

The type concept serves as a standard of reference to tie taxonomic names to objectively recognizable taxa. The standards are the types and the types are only the specimens bearing the name of the taxon. A type is always nothing more than a zoological object. In this regard and for the sake of standardization in systematics in general, only three type concepts (holotype, lectotype, and neotype) currently are exercised in the type method. This standardization unfortunately has a certain sterility. Additional type concepts could alleviate such a situation and simultaneously do systematic science a real service.

These proposed type concepts and their use were hypothesized, distilled, crystallized, and recrystallized through creative deliberative debate with members of the Association of Minnesota Entomologists and several other distinguished entomologists. They were found to apply in one situation or another where no other concept seemed quite appropriate. With few exceptions, *all* these type concepts have been found to have a usefulness apparently unappreciated by the systematic entomologist. The reader should be aware that these proposals are an attempt at satirical humor on taxonomic entomology.

Ambiguotype. 1. A type specimen, usually a holotype, with inadequate date-locality labels. Classics are: "N. Amer.", "Northwest Territory", "my backyard", "Summer 69", "Highway 313", etc. 2. Also known in some circles as a type based on a "Walker description" or as a "Walker type".

Artotype. Type specimen of a new species with distinctive color patterns ultimately shown to be paint spots.

Atypicotype. Type specimen of a new species ultimately recognized as a color variant of a well known common species. Coleopterists familiar with the work of Casey are well acquainted with this type concept.

Autotype. Holotype collected from the grill or radiator of your car.

Biasotype. Type specimen of a species recognized as distinct by detailed statistical treatment involving a small sample size (one or two).

Boobootype. A holotype that should not have been described. In this case, a specialist fails to recognize his own earlier described species; the museum technician or the star graduate student does, however.

Chromosomotype. A type specimen of a new species known only from its chromosome smear because the remainder of the specimen was discarded.

Collectotype. The type specimen of a new species instantly recognized by an authority but in the personal collection of a collector who will not give it up under any circumstances.

Constructotype. A holotype (created during a taxonomic revision) due to a mix-up of body parts, such as male genitalia on a female body, etc.

Curatotype. This type category is retained for those specimens placed under the curator's stewardship which demonstrate a high degree of technical expertise: 1) the spiral staircase and the parking ramp space savers (Figs. 1 and 2); 2) the cheap pin trick in which the pin bends with every touch or slowly corrodes away (Fig. 3); 3) brittle glue trick (Fig. 4); 4) celluloid points with a special PDB twist (Fig. 5); 5) glop on a pin trick for when you run out of points (Fig. 6); 6) the soft-bodied bug trick-before and after (Fig. 7); 7) the tape and glass block trick used on lepidoptera to avoid examination with a microscope.

Cryptotype. A type described and published in something like *Turtox News, Ranger Rick,* a personal letter to mom, or a mimeograph mailed to your cronies.

Dermestotype. A holotype usually consisting of only a partial thorax and some attached legs topped by artifacts reminiscent of a dermestid orgy.

Diplomatotype. A type named for someone with whom the describer wishes to have a good rapport, ie. *Nationalsciencefoundationulus, NIHulus, Racquelwelchae,* etc.

Dissectotype. The type specimen of a species recognized to be new after you have dissected the beast entirely. Often the dissectotype can be cleverly converted to a Dermestotype.

Hoaxotype. A unique type, constructed of parts and pieces of several unrelated higher taxa (grasshopper head, beetle body, moth wings, etc.). This kind of specimen often appears on a practical exam where the instructor feels he has a sense of humor and the students do not.

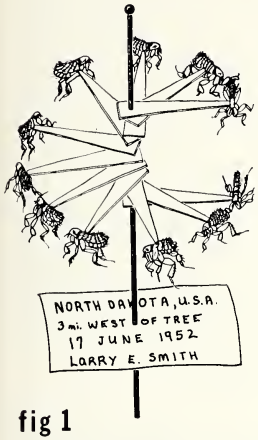


fig 1

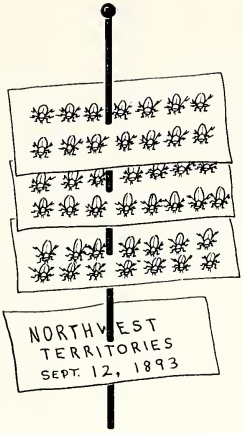


fig 2

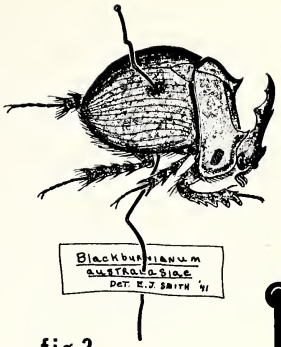
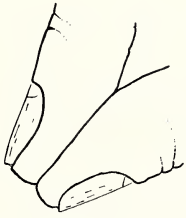


fig 3



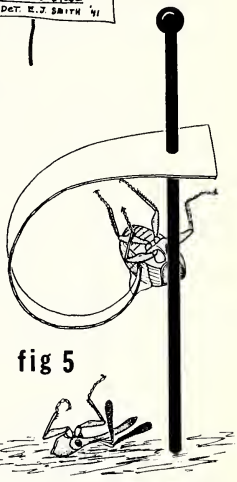


fig 5

fig 4

fig 6

before

fig 7

after

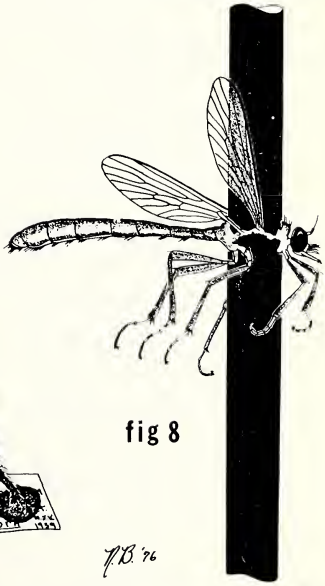


fig 8

FIGS 1–8.

Immaturotype. This type category is for specimens of species with previously unknown larval or nymphal stages. There was considerable deliberative discussion concerning this particular type since a number of our peers felt there should be a breakdown into several categories more explicit in denoting the type of immature being considered. Type concepts such as larvotype, pupotype, maggototype, caterpillarotype and nymphotype received considerable support. It was decided to retain Immaturotype however, when our most distinguished and literate colleague reduced the debate to irretrievable absurdity by demanding nymphotype be retained for a particularly fascinating female *Homo sapiens* of his close acquaintance.

Incognitotype. 1. The type specimen which is positively the holotype but has lost its identifying labels. 2. A type created when the holotype is deposited in a personal collection which ultimately disappears. 3. A holotype, presumed lost, which is needed for a major taxonomic revision.

Kleptotype. A type which has been stolen from its rightful place.

Patronymotype. A holotype in the personal collection of a collector who will relinquish it to a recognized authority if the new species is named after the collector and he gets to keep the holotype.

Pornotype. A type category frequently used in entomological circles (but never recognized in the scientific literature) in which systematic decisions are based predominately on extensive examination of genitalia. In some cases, it is difficult to ascertain whether pornotypy is a matter of personal taste or a necessary professional evil.

Progressotype. Holotype of a species (now probably extinct) whose original habitat was restricted to an area now known as Miami, Florida or San Francisco Bay, California.

Publishotype. Holotype described after rumors of staff reduction are circulated. Known in some circles as "boiling the pot."

Solutotype. A type created by dissolution in NaOH or KOH, usually while the author is momentarily engaged in a caffeinated discussion with several peers.

Teletype. A holotype whose description reads like a report of the New York Stock Exchange and has about as much usefulness.

Tyrannotype. Type designated by the International Commission on Zoological Nomenclature. Apparently a necessary evil.

Vampirotype. A type specimen created when an oversized insect pin is plunged thru an undersized insect. The result is a head on one side of the pin and a

partial abdomen on the other side connected by miscellaneous pieces of strained flesh. Named for its analogy to using wooden stakes to kill vampires (Fig. 8).

Corollary Scientific Terminology

Taxonomists Piece. That anatomical structure (whose function is unknown) used by professionals to facilitate easy recognition of a particular taxon.

These type concepts were found to apply to scientific enigmas for which no other answer existed. In spite of the gravity of this point, and the scientific creativity involved in the writing and publication of scientific truths such as these, the authors want nothing whatever to do with this classic. This decision was arrived at after it was kindly demonstrated that democratic justice operates on the principle of "innocent until proven guilty" and also that any resemblance to current systematic or taxonomic research had better be purely coincidental. The apparent authors therefore stand accused of complicity only in publication, not necessarily authorship.

BOOK REVIEW

Mites Injurious to Economic Plants. Lee R. Leppson, Hartford H. Keifer and Edward W. Baker. University of California Press. 614 pp. 42 original drawings and 80 photographs. $??. 1975.

This book presents a readable, authoritative treatment of all available information on mites that cause injuries to economically important food and fiber plants, and to ornamentals. The distribution, biology, types of injury, chemical control, as well as keys for the identification of mites are included. Eight chapters provide an in depth description of mite biology. Five chapters are devoted to descriptions of mites that cause injuries to economic plants. The authors are renowned world authorities in different areas of acarology and the book will be of great value to research workers in entomology, as well as to students, teachers, county agents and experimental stations. The illustrations, including beautiful scanning electron micrographs, will be of special help to those interested in mite taxonomy. Unfortunately the proofreading of the book was done in a sloppy manner and the reader ought to be cautioned about the reliability of references and spelling. I will quote but a few examples picked at random. Slykhuis on p. 100 is also spelled, erronously, as "Slykhius." The reference to his work on p. 102, quotes his article in "Smith, K. M. : Adv. in Virus Res. 11:97–137, Laufer, Academic Press, N. Y.-London." The reference should have been to "Advances in Virus Research edited by Smith, K. M. and Laufer. Max A." "Transmission of Agrophyon mosaic virus. . . ." should have read Agropyron mosaic virus. The sentence pertaining to mites as vectors of plant viruses on p. 94 is perplexing: "Mites belonging to the Eriophyoidea have been known since 1933 to transmit plant viruses (Amos et al, 1927). . ." How did Amos et al in 1927 know what would be known since 1933? In fact, the association of the current reversion disease with mites was known, but the causative virus was not linked with mites until many years later and reversion was considered due to mite injury. The important contribution of Slykhuis, who discovered that eriophyid mites transmit viruses, was not properly emphasized in this book.

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Oviposition Behavior and Host Feeding of *Asaphes lucens*[1] an Aphid Hyperparasitoid[2]

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Received for Publication May 12, 1976

Abstract: The behavioral study of the hyperparasitoid *Asaphes lucens* was greatly facilitated by the development of a technique which partially exposed its host *Aphidius smithi* within the mummy. This exposure allowed direct observation of ovipositional exploration, host venomization, feeding tube formation, and actual egg deposition.

After antennal investigation of the mummy surface, the *A. lucens* female spent an average of 4.3 min drilling through the mummy to reach the host. The hyperparasitoid then used her ovipositor to explore the host, spending an average of 7.5 min in this activity. Prior to the first oviposition, *A. lucens* always constructed a feeding tube from host body to mummy surface, and then fed for an average of 5 min. Once feeding was completed the tube was always broken by a reinsertion of the ovipositor.

Successful biological control programs demand not only a thorough understanding of those insect populations directly involved, but require a study of peripheral factors as well. For this reason we have investigated the ovipositional and host-feeding behavior of the hyperparasitoid *Asaphes lucens* (Provancher) as it attacks the primary parasite *Aphidius smithi* Sharma and Subba Rao. A detailed knowledge of the biology and behavior of the hyperparasitoid is important if the entire complex of host-primary parasite-secondary parasite is to be understood.

Extensive reviews of the biology, ecology and impact of aphid parasitoids in general were made by Clausen (1940), DeBach (1965) and Hagen and van den Bosch (1968), but very little work has been directed specifically toward the aphid hyperparasitoid *A. lucens*. Griswald (1929) discussed the immature stages of *A. lucens* and certain aspects of the behavioral pattern of this species have been investigated and recorded by Spencer (1926) who observed that *A. lucens* examines the aphid mummy prior to attacking the primary parasite it contains. Sekhar (1958) examined the drilling process which gives the parasitoid access to its host, thus allowing for oviposition, but host feeding was not observed in

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[1] Hymenoptera: Pteromalidae

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A. lucens. However, Sullivan (1972) did report this behavior in another species, *A. californicus*.

The present investigation was undertaken to examine in detail the ovipositional behavior of *A. lucens*, to determine whether or not this species follows the usual pattern of other nonaphid attacking Pteromalids, and whether it does indeed host feed. The development of a technique whereby the interior of the aphid mummy could be viewed during the entire ovipositional act greatly facilitated this study.

MATERIALS AND METHODS

The pea aphid *Acyrthosiphon pisum* (Harris) served as host in this study, and was reared on broad bean, *Vicia fava* Linnaeus (Windsor variety). *A. smithi* Sharma and Subba Rao, the primary parasite, and *A. lucens* (Provancher), the hyperparasitoid, were reared with the plants and aphids in a temperature cabinet (percival Environator, Model E–54U).

To observe the process of oviposition or feeding tube formation, a parasitized aphid or "mummy" was affixed, ventral side down, to a 3 cm square of paper in a drop of Elmer's Glue-All (Borden Chemical Co.). Using a micro-scalpel and a microprobe, one lateral surface and half the dorsal surface of the mummy were cut away, thus partially exposing the primary parasitoid, and still allowing sufficient dorsal surface for the hyperparasitoid to take the ovipositional stance and begin drilling. In this way, the action of the ovipositor within the mummy and feeding tube formation could be observed.

RESULTS AND DISCUSSION

Ovipositional behavior. The process of oviposition by *A. lucens* was both preceded and followed by a fairly predictable behavior pattern. The female approached the aphid mummy containing the primary parasitoid and began an intensive examination, consisting first of rapidly walking around, and sometimes over, the mummy. This initial exploration usually lasted only a few seconds and was then followed by a more lengthy period of antennal tapping, extending from 1 to 30 seconds. The parasitoid bent her antennae downward and appeared to use them to examine most of the mummy surface. At times her abdomen would be stretched out just above the mummy, in an almost "listening" posture. Occasionally, the examination proceeded no further than this. For some reason, the female would simply leave the mummy, perhaps to return and repeat the process, or perhaps to find another more suitable host.

Should the investigation continue, the female was seen to squat slightly and lightly tap the mummy with the tip of her abdomen, apparently searching for the right location for the insertion of her ovipositor. When this spot was found,

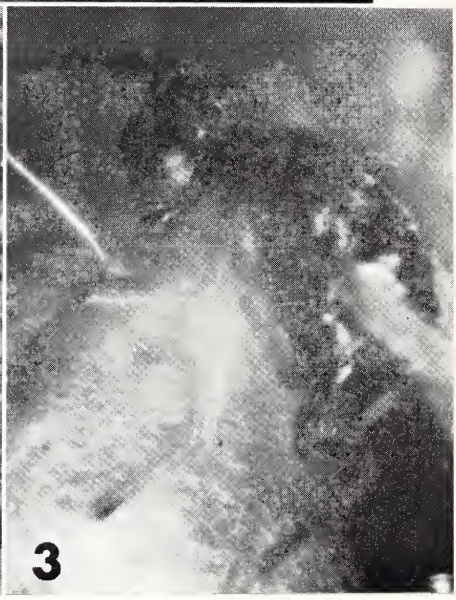

Fig. 1. —Two *lucens* hyperparasitoids attacking a mummy containing the primary parasitoid *A. smithi*. The female in the lower right is examining the mummy with her antennae, while another female drills with her ovipositor.

Fig. 2. —Partially opened mummy showing transparent feeding tube (a) extending from *A. smithi* larva to the surface of the mummy. (Retouched photograph).

Fig. 3. *A. lucens* female feeding at drill hole.

usually after an average of 1.5 min, the preliminary phase of oviposition ended and the drilling phase began (Fig. 1).

While drilling, *A. lucens* assumed a characteristic stance. The body was in a squatting, partly vertical position, head and antennae were bent downward, the legs were apart, and the feet were firmly anchored on the mummy surface, giving leverage to the ovipositor. Drilling was accomplished by a circular rotation of the ovipositor, and by an up and down movement of its valves against each other. Once drilling was completed, the ovipositor was thrust completely into the mummy, so that at times the female's abdomen touched the mummy surface.

The amount of time necessary for the female to successfully drill through the aphid mummy varied greatly, depending on the density of the cocoon spun within by *A. smithi*. In one instance, 24 minutes were needed, while several females completed the task in 1 minute or less. The average drilling time was 4.3 minutes.

None of the earlier investigators of *A. lucens* (Spencer 1926; Griswald 1929; Sekhar 1958) have recorded what takes place inside the mummy as the female explores with her ovipositor, and finally venomizes and oviposits on the host. The use of a partially opened mummy allowed direct observation of the ovipositor within the mummy.

The female used her ovipositor to probe and stroke the host surface. She reached the most distal parts of the host at least with the tip of her quite flexible ovipositor. The average time spent exploring the host in this manner was 7.5 minutes for each insertion of the ovipositor. If it is customary for the female to spend this amount of time in a tactile study of her host, then it would indicate that the organ of exploration must be equipped with sensory structures of some sort. Several parasitoids have been studied for the presence of just sensory structures and the electron microscope has revealed their presence on the tip and sheath of the ovipositor, as well as the occurrence of sensory pits on the 1st valvulae (Gutierrez 1970; Weseloh 1971, 1972). An EM study of the ovipositor of *A. lucens* may reveal similar sensilla.

Very little work has been done on the venom used by hyperparasitoids. That *A. lucens* does venomize her host has been observed in the course of these investigations. The *A. smithi* larva contracted and jerked away when *A. lucens* explored the host surface; when the ovipositor was inserted into *A. smithi* its activity ceased within an average of 2 minutes. Although Clausen (1940) recorded instances of a 10 minute to an 8 hour lag until the venom of other parasitic Hymenoptera took effect, the venom of *A. lucens* was fast acting. While Beard (1963) insisted that paralyzing venom is not a preserving fluid, several paralyzed *A. smithi* larvae have been found to remain soft and moist up to 14 days, although they had turned brown.

The complete withdrawal of the ovipositor in the species was always preceded by a characteristic movement of the antennae. During the entire process of preliminary investigation, drilling, and host examination, the antennae were bent downward. When the ovipositor was to be finally removed from the mummy, the antennae were raised to a horizontal position and fluttered slightly. This signaled a complete withdrawal of the ovipositor as opposed to the partial withdrawals noted above.

The actual passage of the egg from parasite to host has been observed in this study. Rather than appearing compressed within the ovipositor (Fulton 1933), the egg of *A. lucens* glides along the valves, which appear separated, and serve as rails or guides. There seemed to be no distortion of the egg during oviposition, nor any sudden increase in size immediately after. The egg was usually, but not always, deposited on the inner, ventral curve of the larval or pupal body of the host.

It was not unusual for *A. lucens* to withdraw her ovipositor, sometimes even leave the mummy and return, and then reinsert the ovipositor either into the same hole or drill a new hole. This behavior represents multiple attacks on a single host by the same parasitoid and these data are at variance with the findings of Sekhar (1958). Not only does *A. lucens* sometimes attack the same mummy more than once, as was reported by Sullivan (1972), but an unpredicttable number of eggs are laid as a result of these attacks.

Host feeding. The present observations indicate that not only does *A. lucens* feed at the drill hole, but that it also constructs a semi-transparent feeding tube extending from the surface of the host to the surface of the mummy. After feeding, the ovipositor is always reinserted into the same opening, the feeding tube broken, and the act of oviposition begun. It should be noted, though, that host feeding activity usually accompanies only the first oviposition of a female. Later egg deposition does not include feeding tube construction and host feeding. Using partially opened mummies, the sequence of host feeding behavior was as follows:

1. After drilling through the mummy surface, *A. lucens* paralyzed and examined the host larva with her ovipositor. Several times during this exploratory process, the parasitoid partially withdrew her ovipositor; it was after the last of these partial withdrawals that feeding tube construction was begun.

2. With extreme slowness and deliberation, the ovipositor, still in the original drill hole, was lowered until its tip pierced the body of the primary parasite. Just as slowly and carefully the ovipositor was then completely withdrawn, being continuously twisted until it was free of the mummy. This pains-taking withdrawal usually took from 5 to 19 min, and left behind a feeding tube extending from host to mummy (Fig. 2).

3. Once the ovipositor had been completely withdrawn, *A. lucens* turned and began to feed at the puncture. The average feeding time was 5.3 minutes (Fig. 3).

4. Feeding was always followed by the reinsertion of the ovipositor into the drill hole, and the breaking of the fragile tube with a rapid, thrusting motion. In several instances a marked decrease in the volume of the host could be observed after feeding by *A. lucens*.

5. Normally, eggs were then deposited on the host, the ovipositor withdrawn, and the process terminated.

6. Occasionally however, the ovipositor was first withdrawn and then reinserted into the puncture, and then one or more eggs were deposited on the surface of the *A. smithi*.

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ADDITIONAL ABSTRACTS

FORTY-SEVENTH ANNUAL MEETING EASTERN BRANCH ENTOMOLOGICAL SOCIETY OF AMERICA

Mass Rearing of *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae) for In-host Production of Nuclear Polyhedrosis Virus

R. P. Smith, S. P. Wraight, M. F. Tardiff, M. J. Hasenstab and J. B. Simeone

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Production of large quantities of gypsy moth virus requires rearing, infecting and recovering virus from the insect host. A method of larval rearing and viral recovery evolved at the SUNY College of Environmental Science and Forestry for supplying large numbers of polyhedral inclusion bodies (PIB's) under U.S. Forest Service Contract #42-00-131. Field-collected eggs, held at 1°C and 60% RH were dehaired by vacuum, surface sterilized in 0.1% NaOCl for 30 minutes, rinsed, dried, placed in 20-mesh nylon packets, and incubated at room temperature. Larvae, placed in groups of 12 in 454 gr. waxed cups, were fed a modified ODell and Rollinson (1966) diet (Bio-Serv Inc.). A 2-cm^2 cube sufficed until late third instar when larvae were fed virus-infected diet containing 3×10^6 PIB/ml. After 48 hrs, the cups were punched to regulate humidity, and larvae were fed virus-free diet until harvested. Cadavers were removed by vacuum and blended. The resulting suspension was filtered to remove debris and then refrigerated.

After 1 week this mixture separated into a sediment from which PIB's were obtained through continuous flow centrifugation and a supernatant from which PIB's were obtained through continuous flow centrifugation, both at 9,000 rpms. Resuspended PIB's were counted on a haemacytometer.

In one year, using the man-hour equivalents of four full-time workers, 400,000 larvae were harvested at a cost of 8¢ per larva and a yield of 3.5×10^{14} PIB's.

Population Structure and the Sampling of Insects for Laboratory Colonization

Ian C. McDonald

Each species possesses a basic set of characteristics that distinguishes it from other species. However, data from genetic research have indicated the unique-

ness of each individual in most sexually reproducing organisms. Also, data from studies of populations have provided evidence that (1) no two local populations of a species are identical, and (2) local populations can vary in time. The differences within and among populations are thought to result from genetic adjustments that lead to the production of a phenotype adapted to the local environment. The idea that the types and levels of variation can be related to environmental patterns suggests the need to conduct field research on native populations of insects being considered as candidates for biological and/or genetic control programs. Data from field studies would be invaluable for establishing sampling methods to obtain representative colonies of given species. In the absence of field work, sampling procedures must continue to be haphazard, and the only recommendations possible are as follows:

1. When using members of a species against their native counterparts, it is probably best to establish colonies using as many insects as it is economically feasible to collect from the area where future releases will be made.
2. When introducing an insect into a new area it is probably best to establish colonies using as many individuals as it is economically feasible to collect from an area very similar to the future release site.

Whenever possible, sampling for any colonization program should take into account the activity periods of the insect.

BOOK REVIEW

Mites of Moths and Butterflies. Asher E. Treat. Cornell University Press, Ithaca, N. Y. 362 pp., 150 figs. $35.00. 1975.

This authoritative book is a thorough and definitive treatment of mites associated with moths and butterflies. The author, Professor Emeritus at City University and Research Associate at the American Museum of Natural History, describes all forms of parasitic, stowaway, and transient mites. The introductory chapters describe the early history, as well as the techniques employed in the study of mites. The systematics and biology, occurrence, distribution, and behavior are expertly presented and cross indexed. The excellent illustrations throughout the text increase the value of this classical study. Biological information on all mites associated with Lepidoptera has been summarized. Two keys, to living mites seen at 20–40 × magnification, and to mounted specimens requiring 400–100 × magnification, comprise Appendix A. Host species are listed in Appendix B. Extensive literature citations, a geographic index, and a general index complete the volume. The book is intended for amateur and professional lepidopterists, but it will be of interest to general entomologists as well. It provides the only comprehensive treatment of mite parasites and scavangers found on butterflies and moths worldwide.

Karl Maramorosch
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BOOK REVIEW

Birdwing Butterflies of the World. Bernard D'Abrera. 1975. Lansdowne Press, Melbourne. 260 pp., 300 col. pls., Map. $49.95 (Australian).

The great birdwing butterflies are the most glamorous group of Lepidoptera because of their size, colors, habitats, distribution and (alas!) the great value placed on them by collectors. This is a magnificent monograph of the group which I am sure everybody interested in butterflies or natural history will want to own. The profuse color illustrations with whose accuracy the author was particularly concerned, are as fine as anything I have seen.

Although not a formal taxonomic revision in that it lacks complete synonomies and bibliography, this is a landmark in the scientific study of the group. The author recognizes three genera, (*Ornithoptera*, *Trogonoptera* and *Troides*) 38 species and 88 subspecies. No new names are proposed, but a number of subspecies are raised to species level and quite a few subspecies are sunk as junior synonyms. The author has studied probably more specimens than anyone else, including many types, and has, himself, had extensive field experience in New Guinea, Australia and the Solomon Islands. He has also reared and photographed some of the species. It is unfortunate that the group has been a favorite target for many over-eager namers with little or no discrimination. As a result many so-called 'species' and 'subspecies' were named, sometimes from only one or two specimens, with a frequent basis of wishful thinking. Some names are still represented by only one or a very few specimens.

Life-sized photographs illustrate all species and subspecies, almost always showing the upper sides of both male and female, and usually the undersides as well. In some cases series of specimens are shown illustrating variation. A selection of male genitalia drawings is also shown. (It is a pity that more use could not be made of these.) Various larval stages and the chrysalids of several species are illustrated. A number of very striking photographs show living adults visting flowers, courting or enjoying other activities. Many habit and habitat notes are given, often from the author's own experiences, and a most interesting series of photographs show environments ranging from the Solomon Islands and Australia to New Guinea, Malaysia and Sri Lanka. (Many taxonomists seem to think that this sort of thing is superfluous, or somehow unscientific, ignoring the fact that taxonomy must deal with the whole organism as a part of its environment, not merely with specimens.)

In other publications the author has shown a keen awareness of the need for conservation and the preservation of rare species, which must include protection of their environments. He carries on with this in the present volume, emphasizing the perilous position of many of the birdwings. The inflated prices paid for bootlegged specimens are still stimulating collectors to seek out the rarest species, just as has been done with the birds of paradise. The Australian government has given legal protection to a number of officially declared 'endangered species' but this can be only a partial palliative as long as conscienceless collectors will bid high for specimens. It is to be hoped that the governments of other regions where endangered birdwings occur will at least attempt to control this immoral trade.

Alexander B. Klots
American Museum of Natural History

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CONTENTS

A Review of the Mexican and Central American species of *Strangalia* Audinet-Serville (Coleoptera: Cerambycidae)

John A. Chemsak and E. G. Linsley
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Received for Publication July 8, 1975

Abstract: The Mexican and Central American species of the lepturine genus *Strangalia* are reviewed. All known species are characterized and new distributional records listed. New synonymy is presented and the following new species described: *Strangalia doyeni* (Mexico); *S. montivaga* (Mexico); *S. opleri* (Costa Rica); and *S. westcotti* (Mexico). A key to the Mexican and Central American species of *Strangalia* is provided.

Since the descriptions by Bates (1869, 1872, 1880–1885) of new Central American and Mexican species of *Ophistomis*, there have been relatively few additions to our knowledge of this group. Linsley (1935a,b) proposed names for two species, one each from Mexico and British Honduras, and Chemsak (1969) described seven new species from Mexico and Guatemala (as *Strangalia*). In 1971, Linsley and Chemsak redescribed all of the Mexican and Central American species named by Bates and reassigned them from *Ophistomis* Thomson to *Strangalia* Audinet-Serville.

Most of the species are poorly represented in collections and we have seen less than 200 specimens excluding the Biologia Centrali-Americana material at the British Museum (Natural History). All species are diurnal flower visitors and most appear to be mimics of Ichneumonoidea or other Hymenoptera. There is a pronounced sexual dimorphism and most males have highly modified secondary sexual characters. In some cases sexual dichromatism is so extreme that the two sexes have been named as separate species.

The genus *Strangalia* may be recognized as follows: Head oblique, abruptly and deeply constricted behind eyes, tempora indistinct, front rather short, palpi unequal; eyes large, finely faceted, notched; antennae inserted on front at anterior margin of eyes, outer segments usually slightly thickened, poriferous areas usually present on distal segments, third segment longer than scape, fourth shorter than third, fifth longer than fourth. Pronotum as long as or longer than basal width, hind angles acute, usually not expanded over humeri; sides sinuate; apex narrowly impressed; prosternum shallowly excavated. Elytra

Acknowledgement: This study is one of a number intended for a comprehensive generic revision of the Lepturinae of Mexico. We gratefully acknowledge support from the National Science Foundation through Grant GB-BM574 and the authorities of the following institutions and individuals for loan of specimens: California Academy of Sciences, San Francisco; Canadian National Collection, Ottawa; Essig Museum of Entomology, University of California, Berkeley; J. M. Campbell; H. F. Howden; G. Nelson; and R. L. Westcott.

usually strongly cuneiform, sides narrowing near middle; apices acuminate to obliquely truncate. Legs slender; hind femora carinate dorsally toward base; hind tibiae often carinate internally in males; posterior tarsi slender, elongate, apical segment slender, cleft only at apex. Abdomen of males with last sternite usually deeply excavated and margins expanded, females with last sternite usually shallowly impressed at apex.

Key to the Known Species of Mexican and Central American *Strangalia*

1. Abdomen with last ventral segment elongate, usually deeply excavated with elevated margins or shallowly excavated for part of the length; antennae usually with well developed poriferous areas; body slender, strongly tapering; hind tibiae often carinate along inner margin—Males 2
Abdomen with last ventral segment only slightly longer than fourth, shallowly impressed at apex; antennae with poorly developed poriferous areas; body more robust, less tapering; tibiae never carinate—Females 18

2(1). Posterior tibiae without distinct carinae 3
Posterior tibiae carinate, at least apically along inside edge from base of inner spur 6

3(2). Abdomen with last ventral segment excavated for its entire length 4
Abdomen with last ventral segment excavated for ½ or ⅔ its length 5

4(3). Antennae with very small poriferous areas; elytra brownish with narrowly black lateral and sutural margins and a small black spot on each side at middle. Length, 16–18mm. Sinaloa, Mexico ..... *gracilis*
Antennae with well developed poriferous areas, segments from seventh with a double row; integument black, elytra usually with two yellowish vittae. Length, 22m. Vera Pax, Guatemala ..... *lachrymans*

5(3). Pronotum densely clothed with short, appressed, golden pubescence; elytra all black or with base orange; abdomen with last ventral segment excavated for ½ the length. Length, 16mm. Durango, Mexico ..... *auripilis*
Pronotum very sparsely pubescent; elytra yellowish with dark lateral margins expanding into spots; Abdomen with last ventral segment excavated for ⅔ the length. 10–13mm. Mexico, Guatemala and British Honduras ..... *pectoralis*

6(2). Abdomen with last ventral segment not excavated, sides not expanded 7
Abdomen with last ventral segment excavated, sides expanded to varying degrees 9

7(6). Posterior tibiae with a broad plate at apex; metasternum with two tubercles 8
Posterior tibiae lacking a broad plate at apex; metasternum without tubercles; integument orange and black, elytra narrowly black apically. Length, 13–18mm. Mexico to Oaxaca, Mexico ..... *biannulata*

8(7). Posterior tibiae arcuate, apex with a single spine in addition to the broad plate; integument orange and black, elytra usually unicolorous orange. Length, 15–18mm. Sinaloa, Mexico ..... *palaspina*
Posterior tibiae straight, apex with two spines in addition to the broad plate; integument testaceous and black, elytra narrowly black along sutural and lateral margins. Length, 17–19 mm. Costa Rica ..... *opleri*

9(6). Pronotum very sparsely punctate, punctures scattered 10
Pronotum densely punctate, punctures usually contiguous 12

10(9). Abdomen with last ventral segment narrowly excavated, expanded sides acute at apex, margins of sternites crenulated; elytra testaceous with black spots 11
Abdomen with last ventral segment broadly excavated, expanded sides rounded at apex, margins of sternites simple; elytra black. Length, 14–18mm. Veracruz, Mexico to British Honduras ..... *brachialis*

11(10). Abdomen with apex of last tergite emarginate, angles not spinose. Length, 14–16mm. Panama ..... *saltator*
Abdomen with apex of last tergite notched, angles spinose. Length, 16–17.5mm. Nicaragua to Panama ..... *picticornis*

12(9). Abdomen with last ventral segment very broadly expanded at sides, densely pubescent, fourth segment impressed at apex 13
Abdomen with last ventral segment moderately expanded at sides, expansion not encompassing entire segment, glabrous, fourth segment not impressed at apex 14

13(12). Abdomen with last sternite strongly longitudinally carinate medially, fourth sternite shallowly impressed at apex; integument all black or elytra with broad, testaceous longitudinal vittae. Length, 20–23mm. Oaxaca, Mexico ..... *cavaventra*
Abdomen with last sternite not carinate, fourth sternite deeply impressed over apical ⅓; integument reddish and testaceous, elytra with vague darker spots. Length, 20–25mm. Oaxaca, Mexico ..... *doyeni*

14(12). Pronotum reddish 15
Pronotum black 16

15(14). Antennae black except for extreme apex; abdomen with last ventral segment excavated for its entire length; elytra black with narrowly reddish base. Length, 20–22mm. Sinaloa, Mexico ..... *bicolorella*
Antennae with segments 5–7 all or partially black; abdomen with last ventral segment not excavated for its entire length; elytra black with small pale spots. Length, 19mm. Nayarit, Mexico ..... *westcotti*

16(14). Posterior tibiae curved and expanded near apex; abdomen with last tergite fringed at apex 17
Posterior tibiae not curved or expanded near apex; abdomen with last tergite not fringed at apex; integument black, antennae with last three segments yellow. Length, 14–16mm. Guerrero, Mexico ..... *xanthotelas*

17(16). Abdomen with last tergite emarginate at apex; elytra broadly testaceous with black margins. Length, 19mm. Chiapas, Mexico to Guatemala ..... *dolicops*
Abdomen with last tergite rounded at apex; elytra black. Length, 16–17mm. Guatemala ..... *melampus*

18(1). Antennae all black 19
Antennae variously bi-or tricolored 27

19(18). Elytra with pattern consisting of distinct black spots 20
Elytra unicolorous or vittate or with apex only dark 22

20(19). Pronotum densely punctate; elytra moderately densely punctate 21
Pronotum very sparsely punctate; elytra sparsely punctate, punctures very widely separated; integument yellowish and black, elytra with three black spots and dark apices. Length, 14mm. Panama ..... *saltator*

21(20). Pronotum reddish at sides with a broad median black longitudinal band; elytra with black spots extending out from lateral margins. Length, 10–13mm. Mexico, Guatemala, British Honduras ..... *pectoralis*
Pronotum yellow with a black longitudinal band on each side of middle; elytra with basal dark band extending back over humeri, other black spots not extensions of lateral dark band. Length, 18mm. Nicaragua ..... *belti*

22(19). Elytra black, unicolorous or with pale longitudinal vittae 23
Elytra orange or reddish, often with longitudinal black vittae 25

23(22). Elytra with pale vittae 24
Elytra unicolorous black; pronotum often reddish, very sparsely punctate. Length, 13–19mm. Mexico and British Honduras ..... *brachialis*

24(23). Abdomen with last tergite shallowly notched at apex; pronotum as long as basal width; elytra with two, narrow testaceous vittae extending almost to apex. Length, 13–18mm. Durango and Sinaloa, Mexico ..... *montivaga*
Abdomen with last tergite deeply emarginate, angles produced into obtuse spines; pronotum longer than basal width; elytra with two yellowish, longitudinal vittae. Length, 15–17mm. Oaxaca, Mexico ..... *cavaventra*

25(22). Head orange or with only vertex black; pronotum orange 26
Head completely black; pronotum black or with a median pale stripe; elytra brownish to reddish, often with a narrow dark sutural vitta and dark lateral vittae over apical one-half. Length, 15–18mm. Costa Rica ..... *opleri*

26(25). Head with vertex black; pronotum with dark pubescence at middle; scutellum black; elytra usually black vittate along suture and lateral margins. Length, 16–18mm. Mexico to Oaxaca, Mexico ..... *biannulata*
Head with vertex orange; pronotum gold pubescent at middle; scutellum pale; elytra concolorous orange or black vittate along suture and lateral margins. Length, 13–16mm. Sinaloa, Mexico ..... *palaspina*

27(18). Antennae with basal segments concolorous black or pale 28
Antennae with basal segments orange annulated with black at apices; pronotum densely clothed with golden appressed pubescence; elytra orange or black or a combination of both. Length, 14mm. Durango, Mexico ..... *auripilis*

28(27). Antennae with basal segments orange or yellowish 29
Antennae with basal segments black 30

29(28). Pronotum distinctly shining, very sparsely pubescent; elytra with punctures on basal black chevron separated, not asperate, sides behind middle gradually tapering. Length, 16–18mm. Sinaloa and Colima, Mexico ..... *bicolorella*
Pronotum dull, moderately densely pubescent, elytra with punctures on basal black chevron contiguous, asperate, sides behind middle abruptly tapered. Length, 18–20mm. Nayarit and Oaxaca ..... *doyeni*

30(28). Antennae with apical segments black 31
Antennae with apical segments pale 32

31(30). Pronotum with two longitudinal black vittae; elytra with black spots. Length, 18mm. Nicaragua ..... *belti*
Pronotum concolorous, lacking vittae; elytra with black sutural and lateral stripes. Length, 16–18mm. Mexico to Oaxaca, Mexico ..... *biannulata*

32(30). Elytra at least bicolored 33
Elytra concolorous black; abdomen with last tergite deeply emarginate at apex. Length, 12mm. Guerrero, Mexico ..... *xanthotelas*

33(32). Elytra with definite rounded black spots; pronotal vittae, if present, longitudinal 34
Elytra with oblique black bands which enclose paler areas; pronotal vittae oblique. Length, 15–17mm. Guatemala ..... *melampus*

34(33). Pronotum bicolored; elytra with more than one pair of black spots 35
Pronotum concolorous black; elytra with a single median pair of black spots; legs pale. Length, 12mm. Sinaloa, Mexico ..... *gracilis*

35(34). Abdomen with last tergite emarginate at apex; pronotum with two black vittae .. 36
Abdomen with last tergite rounded at apex; pronotum mostly black, not vittate; elytra with black spots arising from marginal stripes. Length, 14mm. Costa Rica ..... *emaciata*

36(35). Pronotum distinctly densely punctate; elytra densely to moderately densely punctate 37
Pronotum very sparsely punctate; elytra sparsely punctate with a short suberect seta arising from each puncture. Length, 15–20mm. Nicaragua to Panama ..... *picticornis*

37(36). Abdomen with last tergite bilobed at apex, last ventral segment spinose at apex; elytra shining, separately punctate at base. Length, 18mm. Nicaragua ..... *belti*
Abdomen with last tergite emarginate at apex, last ventral segment not spinose at apex; elytra dull, basal punctures contiguous. Length, 18mm. Mexico .. *sallaei*

Strangalia auripilis Chemsak

Strangalia auripilis Chemsak, 1969, Jour. New York Entomol. Soc., 77:6, fig. 5; Linsley and Chemsak, 1971, Arq. Zool., 21:24.

Male: Color black and orange, variable, elytra often with base orange, antennae orange and black basally, legs bicolored, pubescence mostly golden. Antennae with small poriferous areas. Hind tibiae not carinate. Abdomen with last sternite excavated for about half its length, margins moderately produced, narrowly elongating at apex. Length, 16 mm.

Female: Form more robust. Abdomen with apex of last sternite impressed at middle giving a scalloped appearance. Length, 14 mm.

Type locality: 24 miles W La Ciudad, Durango, Mexico.

Known only from the type series collected in July. Considerable variation is expressed in the coloration. The coloration of the elytra may be wholly black or orange or a combination of the two. The coloration of the legs and under surface is also variable.

Strangalia belti (Bates)

Ophistomis belti Bates, 1872, Trans. Entomol. Soc. London, 1872:182; Bates, 1880, Biologia Centrali-Americana, Coleoptera, 5:39, pl. 4, fig. 22.

Strangalia belti; Linsley and Chemsak, 1971, Arq. Zool., 21:24.

Female: Form moderately robust, elytra attenuated; color yellowish orange, parts of head, antennae at least basally, two pronotal stripes, parts of legs and underside black, elytra with black humeral bands, two median spots, a post median stripe and apices narrowly, suture black to about middle. Pronotum moderately densely, irregularly punctate, median lines glabrous; pubescence moderately dense, rather long, subdepressed. Abdomen almost impunctate; last sternite impressed at apex; angles spinose; last tergite bilobed at apex. Length, 18 mm.

Male: Unknown.

Type locality: Chontales, Nicaragua.

This species is distinctive from others with similar coloration by the punctate and pubescent pronotum and by the shape of the last abdominal tergite. It is presently known only from the type.

Strangalia biannulata (Linsley)

Ophistomis biannulatus Linsley, 1935, Trans. Amer. Entomol. Soc., 61:83.

Strangalia biannulata; Linsley and Chemsak, 1971, Arq. Zool., 21:25.

Male: Form slender, tapering; color orange with parts of head, elytra, underside, legs, and antennae black. Antennae with well defined poriferous areas. Pronotum with short, depressed, dark pubescence on disk. Legs with hind tibiae with a small tubercle at inside before apex. Abdomen with last sternite elongate, very shallowly impressed at apex, sides not inflated. Length, 13–18 mm.

Female: Form a little more robust. Abdomen with last sternite irregularly truncate at apex, shallowly impressed at middle. Length, 16–18 mm.

Type locality: Bejucos, Temescaltepec, Mexico, Mexico.

Color variation is considerable especially in the elytra. These range from orange with black apices to longitudinally black vittate to all black with orange humeri and basal margin.

In addition to the type series, the following specimens, all from Mexico have been examined: 1 ♀, 20 miles E El Camaron, Oaxaca, 21 July 1956 (J. W. MacSwain; 2 ♀ ♀, 14 miles NW Tehuantepec, Oaxaca, 26 June 1961, on flowers of *Croton* (U. Kans. Mex. Exped.); 3 ♂ ♂, 3 ♀ ♀, 30 miles NE Tehuantepec, 8 July 1955 (D. Giuliani); 1 ♀, 16 mi N Juchitan, Oaxaca, 2 July 1955 (R. Beer and party); 1 ♂, 6 miles S Rio Mexcala, Hwy. 95, Guerrero, 6 August 1965 (G. H. Nelson); 1 ♀, 15 miles S Iguala, Guerrero, 10 July 1966 (P. M. & P. K. Wagner); 1 ♂, Cuernavaca, Morelos, 29 July 1961 (R. & K. Dreisbach).

Strangalia bicolorella Chemsak

Strangalia bicolorella Chemsak, 1969, Jour. New York Entomol. Soc., 77:2, fig. 1; Linsley and Chemsak, 1971, Arq. Zool., 21:24.

Strangalia pulchra Chemsak, 1969, Jour. New York Entomol. Soc., 77:5, fig. 4; Linsley and Chemsak, 1971, Arq. Zool., 21:24. New synonymy.

Male: Color reddish orange except for the following black parts: tips of mandibles and maxillarly palpi, eyes, antennae except scape, elytra except for basal margin, apex of abdomen, tibiae and tarsi and apical halves of hind femora. Antennae with distinct poriferous areas on distal segments. Elytra strongly acuminate; punctures rather fine, separated. Legs with

hind tibiae carinate internally. Abdomen with last ventral segment excavated for its entire length, margins strongly expanded. Length 20–22 mm.

Female: Form strongly tapering posteriorly; color reddish, elytra yellowish and brown with black fasciae, antennae reddish basally, segments six and seven dark, remaining segments yellow, underside variably partially black. Abdomen with last sternite medially impressed at apex, apical margin uneven, sides subdentate. Length, 16–18 mm.

Type locality: of *bicolorella*, *pulchra*, 5 miles N of Mazatlan, Sinaloa, Mexico.

This species is strongly sexually dichromatic and the above synonymy was determined only by collecting mating pairs.

In addition to the type series, material examined from Mexica includes: 2♂♂, 2♀♀, 2.5 miles N Mazatlan, 10–11 August 1970, on flowers of *Buddleia wrightii* (J. A. Chemsak); 1♀, La Audiencia, 7 miles NW Manzanillo, Colima, 25 August 1970 (C. E. and D. E. Wasbauer); 1♂, 1♀, 5 miles N Mazatlan, 31 July 1972, on *B. wrightii* (J. and M. A. Chemsak, A. and M. Michelbacher).

Strangalia brachialis (Bates)

Ophistomis brachialis Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:280.

Strangalia brachialis; Linsley and Chemsak, 1971, Arq. Zool., 21:26.

Ophistomis nigrita Linsley, 1935, Trans. Amer. Entomol. Soc., 61:110.

Male: Form elongate, strongly attenuated; color black, front and middle legs often partially yellowish. Antennae with large poriferous areas. Pronotum shining, very sparsely punctate, non pubescent. Legs with hind tibiae carinate. Abdomen with last sternite excavated for its length, sides moderately produced. Length, 14–18 mm.

Female: Form more robust, less attenuated. Abdomen sparsely punctate, last sternite lightly impressed at apex. Length, 13–19 mm.

Type locality: of *brachialis*, Oaxaca, Mexico; *nigrita*, Punta Gorda, British Honduras.

Females often have the pronotum and underside reddish and one specimen has reddish longitudinal vittae on the elytra.

Specimens examined from Mexico and not previously recorded include: 1♂, 3♀♀, Cordoba, Veracruz, 12 July 1936 (J. S. Buckett, M. R. and R. C. Sears); 1♂, Presidio, Veracruz, 1 July 1964 (Lau); 1♀, Lago Catemaco, Veracruz, 14 July 1968 (M. Wasbauer, J. Slansky); 1♂, Coyame, Lago Catemaco, 1–15 July 1963 (D. R. Whitehead); 3♂♂, 1♀, X-Can, Quintana Roo, 2–12 July 1967 (E. R. Welling).

Strangalia cavaventra Chemsak

Strangalia cavaventra Chemsak, 1969, Jour. New York Entomol. Soc., 77:8, fig. 7; Linsley and Chemsak, 1971, Arq. Zoo., 21:24.

Male: Form slender, elongate; color black, elytra often with two pale longitidinal vittae. Antennae with small poriferous areas. Legs with hind tibiae strongy carinate internally. Abdomen with last sternite deeply excavated, broadly carinate medially, margins very strongly inflated, clothed internally with long and short erect pubescence. Length, 20–23 mm.

Female: Form similar, elytra strongly cuneiform. Abdomen reddish, apex of last tergite strongly emarginate, apex of last sternite medially impressed. Length, 15–17 mm.

Type locality: 14 miles W Tehuantepec, Oaxaca, Mexico.

Additional material includes 5 males, 1 female, 30 miles NE Tehuantepec, 8 July 1955 (D. Giuliani).

Strangalia dolicops Chemsak

Strangalia dolicops Chemsak, 1969, Jour. New York Entomol. Soc., 77:3, fig. 2.

Male: Form slender, elongate, strongly attentuated; color black, antennae with segments 7 or 8 to 10 yellowish, at least beneath, elytra with broad testaceous, longitudinal vittae. Poriferous areas of antennae very small. Pronotum with discal punctures dense, strongly transverse, pubescence fine, sparse. Legs with hind tibiae vaguely carinate internally. Abdomen with last sternite excavated for its entire length, margins moderately strongly produced. Length, 19 mm.

Female: Unknown.

Type locality: Santa Clara, in interior valley of Sierra de las Minas (N. of Cabanas), Zacapa, Guatemala, 6,500 ft.

This species is distinctive by the long, slender face and almost angulate sides of the pronotum.

Additional material: 1♂, Ach'lum, Tenejapa, Chiapas, Mexico, 8900 ft., 23–26 July (D. E. Breedlove, J. Emmel).

Strangalia **doyeni**, n. sp.

Male: Form rather robust, elongate, strongly tapering posteriorly; integument yellow-orange, tips of mandibles and palpi, eyes, neck beneath, antennae except scape above and outer segments, margins of pronotum and margins of thoracic sternites black, elytra with pale brownish humeral stripes terminating into spots which extend to suture as basal one-fifth, two brownish ante-median spots extending from margins and apices brownish. Head with front long, shallowly, separately punctate, pubescence obsolete; vertex finely, confluently punctate, very sparsely pubescent; antennae thickening from sixth segment, shorter than elytra, scape pale dorsally, segments from sixth with distinct apical poriferous areas. Pronotum with sides slightly sinuate, apex narrowly impressed; disk strongly convex with a vague median line; punctures transverse, confluent, finer at sides; pubescence fine, depressed, black on disk, golden at basal margin; prosternum very finely rugulose, sparsely pubescent; meso- and metasternum finely, shallowly, densely punctate, densely clothed with golden depressed pubescence. Elytra more than three times as long as broad, strongly attentuated and dehiscent; punctures fine, contiguous; pubescence moderately dense, subdepressed, black and golden; apices obliquely truncate, not produced. Legs slender, hind femora carinate basally on inside edge; hind tibiae strongly arcuate, strongly carinate internally, inner tibial spurs modified into small flat plates. Abdomen extending almost two segments beyond elytra; first three sternites minutely punctate basally at sides, punctures becoming coarser and sparser toward apex, fourth sternite finely densely punctate and pubescent, impressed over apical one-third, last sternite deeply excavated, sides strongly produced, densely clothed with erect pubescence internally. Length, 20–25 mm.

Female: Form similar, elytra strongly attenuated. Antennae extending to about third abdominal segment, segments to fifth orange, sixth and part of seventh black, remainder yellow, poriferous areas small. Elytra with a broad black band at basel one-fifth which expands along suture to scutellum and joins an antemedian black band, apical half brownish, pale areas between bands yellow. Abdomen with last sternite strongly impressed at apex; last tergite emarginate at apex, angles obtuse. Length, 18–20 mm.

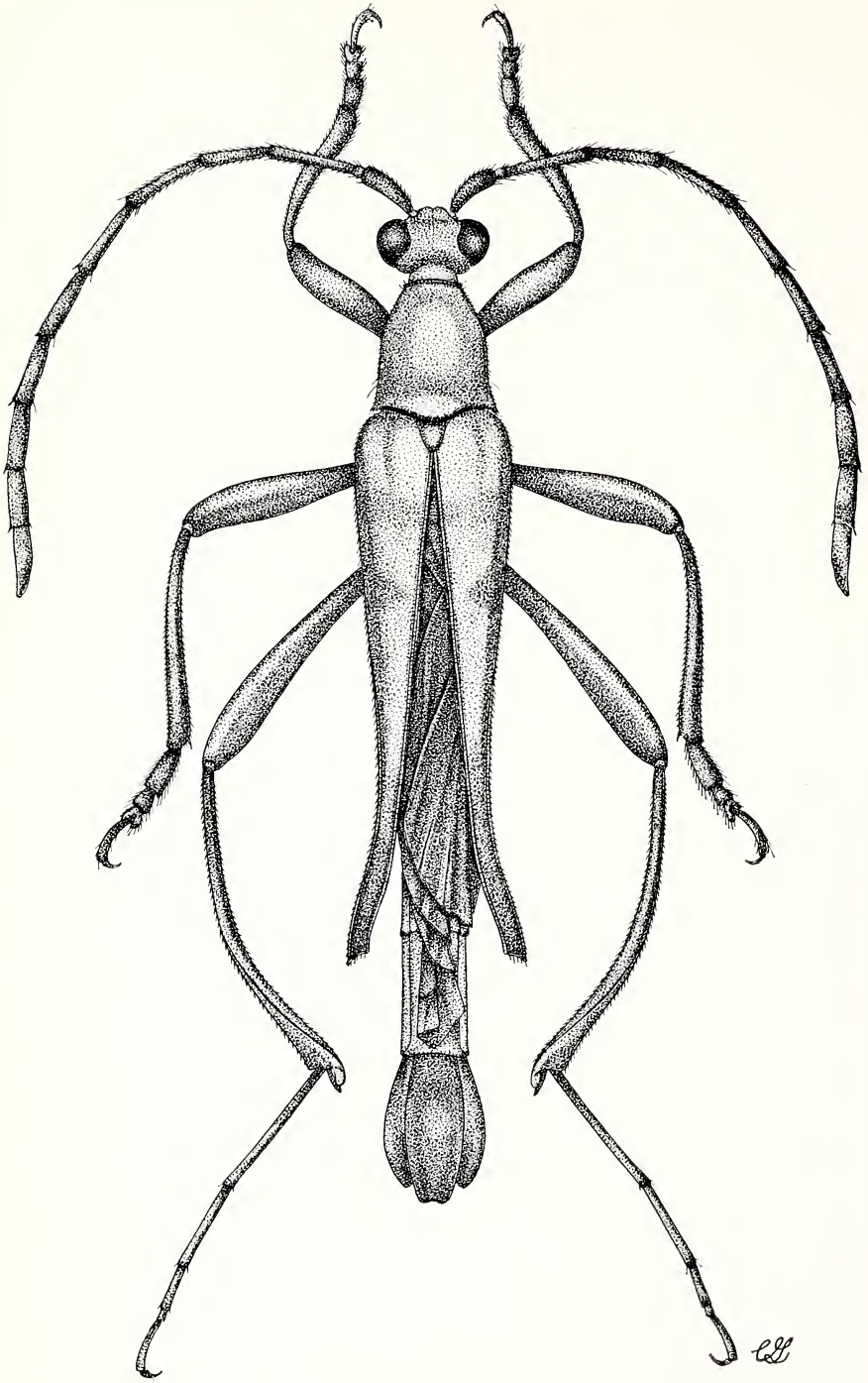

FIG. 1 Strangalia doyeni Chemsak and Linsley. ♂

Holotype male, allotype (California Academy of Sciences) and 10 paratypes (8 males, 2 females) from 30 miles NE Tehuantepec, Oaxaca, Mexico, 8 July 1955 (D. Giuliani). Additional paratypes include: 1 male, 8 miles N. La Ventosa, Oaxaca, Mexico, 20 July 1963 (J. Doyen); 1 male, 4 miles E. San Blas, Nayarit, Mexico, 17 July 1963 (J. P. Donohue).

There is little variation in coloration among individuals of the same sex. The females resemble those of *bicolorella* but may be separated by the dull, pubescent pronotal disk and more finely punctate elytra.

We are pleased to dedicate this species to John T. Doyen who first brought it to our attention.

Strangalia emaciata (Bates)

Ophistomis emaciata Bates, 1880, Biologia Centrali-Americana, Coleoptera, 5:39.

Strangalia emaciata; Linsley and Chemsak, 1971 Arq. Zool., 21:27.

Female: Form slender, elytra attenuated; color yellowish, most of head and pronotum, antennae except segments 6 to 10, parts of legs and underside black, elytra yellow except scuteller area, a diamond shaped sutural spot behind scutellum which narrows and extends down suture to apex, past humeral spots and triangular antemedian spots not attaining suture. Pronotum very sparsely punctate, non pubescent. Abdomen subglabrous; last sternite impressed at apex, angles dentate; last tergite rounded at apex. Length, 14 mm.

Male: Unknown

Type locality: Costa Rica

This species, known only from the type, is distinguished by the very sparsely punctate pronotum and the shapes of the last abdominal tergite and sternite.

Strangalia gracilis Chemsak

Strangalia gracilis Chemsak, 1969, Jour. New York Entomol. Soc., 77:7, fig. 6; Linsley and Chemsak, 1971, Arq. Zool., 21:24.

Male: Form very slender, strongly tapering; color black with brownish elytra which are narrowly black along the lateral and sutural margins, each side with a small black spot at middle near lateral black line. Antennae with very small poriferous areas. Legs with posterior tibiae lacking carinae. Abdomen with last sternite excavated for its entire length, margins moderately strongly expanded, excavation almost glabrous. Length, 16–18 mm.

Female: Form less attenuated. Antennae with last four segments yellow. Legs pale. Abdomen reddish; last abdominal sternite apically impressed at middle. Length, 12 mm.

Type locality: 15 miles W El Palmito, 5,000 feet, Sinaloa, Mexico. Only the type series, collected in July, has been seen.

Strangalia lachrymans (Bates)

Ophistomis lachrymans Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:280, pl. 20, fig. 4.

Strangalia lachrymans; Linsley and Chemsak, 1971, Arq. Zool., 21:28.

Male: Form large, strongly attenuated, color black, elytra with two short yellowish longitudinal vittae. Antennae with poriferous areas, segments from seventh with a double set

of two poriferous spots. Pronotum densely, confluently punctate, punctures transverse; pubescence sparse, short, erect. Legs with hind tibiae not carinate. Abdomen with last sternite excavated for its length, sides strongly expanded. Length, 22 mm.

Female: Unknown

Type locality: Purula, Vera Paz, Guatemala

Although this species is known only from the type, the color pattern probably varies from all black to black with well developed pale vittae on the elytra.

The robust size, nature of the punctures and pubescence of the pronotum, rather sparsely punctate elytra, and strongly expanded apex of the abdomen should make *lachrymans* readily recognizable.

Strangalia melampus (Bates)

Ophistomis melampus Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:280.

Strangalia melampus; Linsley and Chemsak, 1971, Arq. Zool., 21:29.

Ophistomis histrio Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:281, pl. 20, fig. 3; Chemsak, 1964, Jour. Kansas Entomol. Soc., 40:78. New synonymy.

Strangalia histrio; Linsley and Chemsak, 1971, Arq. Zool., 21:27.

Male: Form moderate-sized, slender, strongly attenuated; color black, antennal segments from sixth usually yellow, legs often partially pale, elytra may have pale spots. Antennae with small poriferous areas. Pronotum densely, transversely punctate except for median glabrous line; pubescence fine, sparse. Legs with hind tibiae carinate at apex. Abdomen with last sternite excavated for its length, sides moderately strongly produced. Length, 16–17 mm.

Female: Form moderately robust; color yellowish, parts of head, antennal segments one to six, margins and two oblique discal stripes of pronotum black, elytra with dark markings as follows: a median semicircular band behind scutellum, an arcuate W-shaped stripe extending obliquely on each sides from humeri, angling sharply, arcuately toward base and ending in a round spot near suture, each side with an oblique V-shaped stripe at middle which extends to suture, a post median oblique line angling toward base at suture and two small spots before apex, the areas contained within the black lines are paler yellow. Abdomen with last sternite feebly impressed at apex. Length, 15–17 mm.

Type locality: of *melampus*, San Geronimo, Guatemala; *histrio*, Cerro Zunil, Guatemala.

The sexual dichromatism in this species is as extreme as that in *S. bicolorella*.

Previously unrecorded specimens include a mating pair from 2 Km N Santa Maria, near tunnel, Quetz., Guatemala, 24 October 1965, (J. M. Campbell).

Strangalia **montivaga**, n. sp.

Female: Form moderate sized, strongly tapering posteriorly; integument black, abdomen reddish, elytra with two narrow, longitudinal, yellowish vittae. Head with front short, frons densely, shallowly punctate, sparsely pubescent; vertex deeply, contiguously punctate, very thinly pubescent; antennae extending to about third abdominal segment, segments from sixth opaque, slightly thickened, poriferous areas vague. Pronotum about as long as basal width, sides slightly sinuate; apex narrowly impressed; disk convex, glabrous median line short, narrow; punctures moderately coarse, subconfluent, ovoid, becoming finer and denser toward sides; pubescence short, depressed, pale basally; prosternum minutely, densely punctate

before coxae, subglabrous toward apex, meso- and metasternum finely, densely punctate, densely clothed with depressed pale pubescence. Elytra about three times as long as broad, sides narrowing before middle; punctures rather fine, subcontiguous; pubescence moderate, short, depressed, mostly dark; apices obliquely truncate. Legs slender; hind femora carinate above at base; hind tibiae not carinate. Abdomen with sternites minutely punctate at bases, punctures becoming larger and very sparse to apical margins; last sternite impressed at middle; last tergite shallowly notched at middle. Length, 13–18 mm.

Holotype: Female (Canadian National Collection) from 24 miles W La Ciudad, Durango, Mexico, 7000 ft., 2 July 1964 (W. R. M. Mason). One female paratype from 15 miles W El Palmito, Sinaloa, Mexico, 29 July 1964 (H. F. Howden).

This species greatly resembles the females of *S. cavaventra*, but in addition to the broader pronotum, it differs by having the apex of the last abdominal tergite shallowly notched with the apices not produced into obtuse spines.

Strangalia **opleri**, n. sp.

Male: Form moderate sized, strongly tapering posteriorly; integument yellowish, head, antennae, most of pronotum, tibiae and tarsi, apices of hind femora, and parts of underside black, elytra narrowly black down suture and margins, more broadly along margins at apical one-half. Head with front only moderately long, rather finely, densely punctate, sparsely pubescent; vertex very finely and densely punctate with a few larger punctures interspersed, densely clothed with fine, golden, recumbent pubescence; antennae shorter than elytra, slightly expanded from apex of sixth segment, segments from seventh opaque, with poriferous areas, basal segments sparsely clothed with depressed black setae. Pronotum elongate, sides slightly sinuate; apex shallowly impressed; disk convex, densely transversely, confluently punctate, punctures at sides deeper, rounded; pubescence dense, golden, appressed, lying transversely at middle; prosternum finely rugulose, moderately densely pubescent; meso- and metasternum finely densely punctate, densely clothed with pale appressed pubescence; metasternum with an elevated tubercle on each side of middle before hind coxae. Elytra almost three times as long as broad, sides strongly narrowing before middle; basal punctures fine, shallow, separated; pubescence pale, moderately dense, depressed, lying obliquely away from suture; apices oblique, shallowly emarginate. Legs robust; front tibiae modified internally, carinate along basal one-half, then forming a concave impression at apex which terminates in a small obtuse spine on each side; hind tibiae with an apical broad plate forming a glabrous concavity to a subapical tubercle. Abdomen extending about two segments beyond elytra; sternites minutely, densely punctate at sides, punctures becoming larger and sparse toward apex, impression very small, sides not produced. Length, 17–19 mm.

Females: Form similar, elytra less attenuated. Antennae extending to about second abdominal segment, outer segments with minute poriferous spots. Legs with tibiae not modified. Abdomen finely, separately punctate; last sternite shallowly impressed at apex; last tergite broadly rounded at apex. Length, 15–18 mm.

Holotype male, allotype (California Academy of Sciences) from Comelco, 8 km. NW Bagaces, Guanacaste Prov., Costa Rica, 25 May 1972, on *Piper pseudofuligineum* (P. A. Opler). Paratypes as follow: 1♂, 1♀. La Pacifica, 4 km NW Cañas, Guanacaste, Costa Rica, 30 May 1972, 2–4 June 1973, on asclepiad vine (Opler); 10♂♂, 2♀♀, Hacienda Comelco, 24 km NW Cañas, Inter-Am. Hwy, Guanacaste, Costa Rica, 14 to 20 May 1971 on flowers of *Piper* and *Allophyllus occidentalis* (E. R. Heithaus).

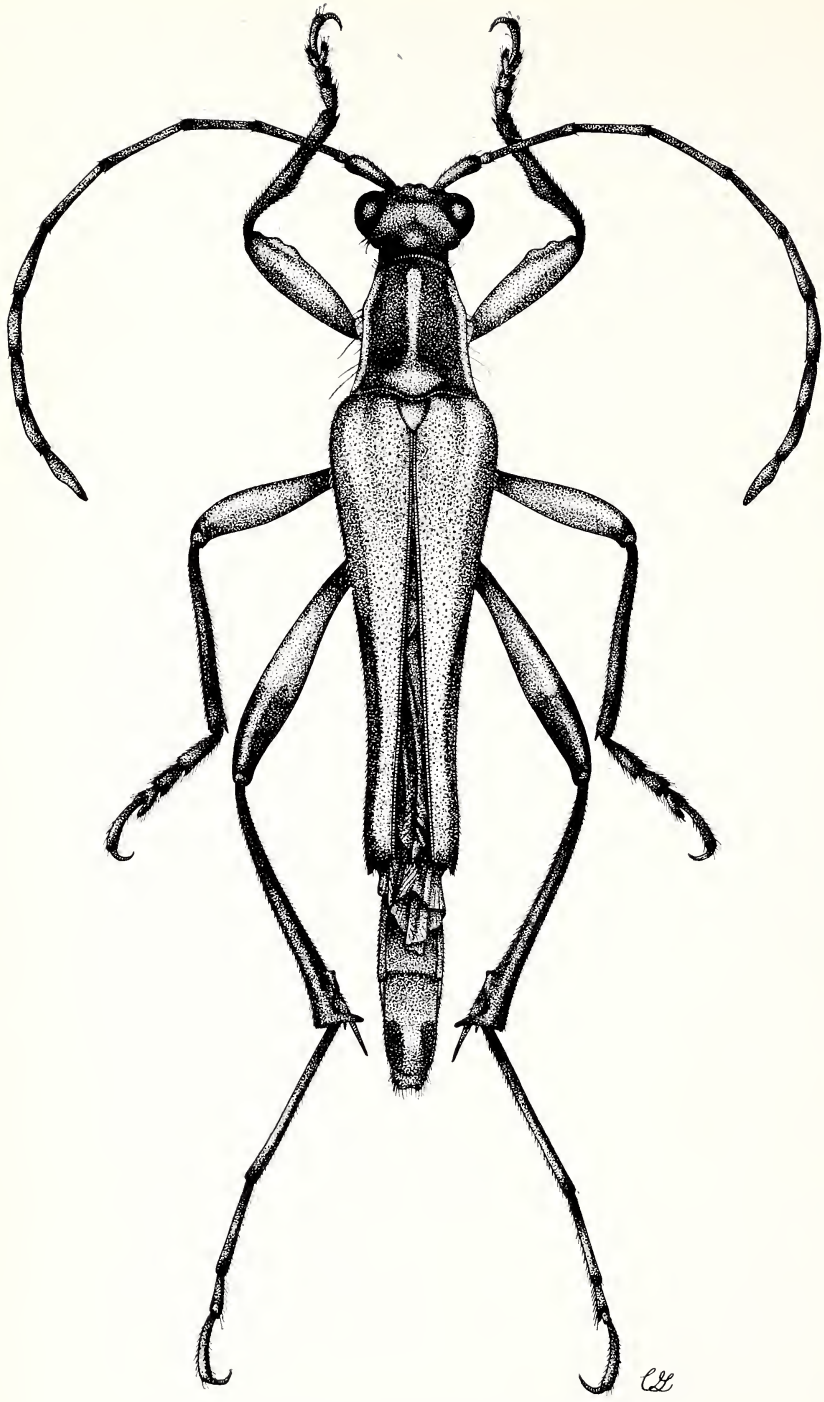

FIG. 2 Strangalia opleri Chemsak and Linsley. ♂

This very distinctive species may be recognized by the yellow and black coloration, the transverse, golden, appressed pubescence, and the secondary sexual characters of the males. Variation is expressed in the amount of black on the pronotum and elytra. Occasionally the elytra are wholly reddish brown.

This species is dedicated to P. A. Opler for his cerambycid collecting efforts over the years.

Strangalia palaspina Chemsak

Strangalia palaspina Chemsak, 1969, Jour. New York Entomol. Soc., 77:3, fig. 3; Linsley and Chemsak, 1971. Arq. Zool., 21:24.

Male: Form moderately slender; color orange with antennae, often apices of elytra, parts of underside and often parts of middle and hind legs black. Antennae with poriferous areas distinct. Hind tibiae with inside spur greatly expanded into a broad excavated plate. Abdomen with last sternite slightly depressed at middle of apex, margins not produced. Length, 15–18 mm.

Female: Form more robust, elytra not attenuated. Abdomen with last sternite short, medially depressed at margin. Length, 13–16 mm.

Type locality: 5 miles N Mazatlan, Sinaloa, Mexico.

The females vary in color with the elytra often having longitudinal black vittae down the margins and suture.

In addition to the type series, 6 males have been examined from the type locality, 22–31 July 1972, taken on flowers of *Buddleia wrightii* (J. and M. A. Chemsak) and 29 July 1973 (Chemsak, Linsleys and Michelbachers).

Strangalia pectoralis (Bates)

Ophistomis pectoralis Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:282; Chemsak, 1964, Jour. Kansas Entomol. Soc., 40:78.

Strangalia pectoralis; Linsley and Chemsak, 1971, Arq. Zool., 21:30.

Male: Form slender, rather small, elytra attenuated; color yellowish except for part of head, pronotum, antennae, parts of legs and parts of underside, pronotum and underside partly reddish, elytra with black spots joined at margins. Antennae with distinct poriferous areas. Pronotum finely, densely punctate, finely, densely golden pubescent. Legs with hind tibiae non carinate. Abdomen with last sternite excavated for about ⅔ its length, sides slightly produced, angles dentate. Length, 10–13 mm.

Female: Form more robust. Abdomen with last sternite medially impressed at apex. Length, 10–13 mm.

Type locality: Cordoba, Veracruz, Mexico.

The densely punctate and pubescent pronotum will distinguish this species from *S. felix* and *S. saltator*.

Previously unrecorded material examined: 1 ♀, Cordoba, Veracruz (A. Fenyes); 3 ♂ ♂, Juquila Mixes, 4700′, Oaxaca, Mexico, 2–7 May 1968 (W. S. Miller).

Strangalia picticornis (Bates)

Ophistomis picticornis Bates, 1869, Trans. Entomol. Soc. London, 1869:384.

Strangalia picticornis; Linsley and Chemsak, 1971, Arq. Zool., 21:30.

Ophistomis felix Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:282, pl. 20, fig. 5.

Male: Form narrow, strongly attenuated; color yellowish, parts of head, two pronotal stripes, antennae, parts of legs black, elytra with two black median basal spots, usually two subbasal spots near margins, a median pair not extending to suture, and a post median pair, apices and margins also narrowly black. Antennae with large, elongate poriferous areas. Pronotum sparsely, transversely punctate, subglabrous. Legs with hind tibiae vaguely carinated at apices. Abdomen with last sternite excavated for most of its length, sides moderately produced, apices dentate. Length, 16–17.5 mm.

Female: Form more robust. Antennae yellow from segment seven. Abdomen with last sternite slender, deeply impressed medially at apex. Length, 15–20 mm.

Type locality: of *picticornis*, Chontales, Nicaragua; *felix*, San Feliz, Panama.

This species is very similar to *S. saltator*, but the slightly more expanded and less acute sides of the last abdominal sternite and deeply V-shaped apex of the last tergite will distinguish the males of *picticornis*. Females of *picticornis* differ in the yellow apices of the antennae and deeply emarginate, dentate last abdominal tergite. Individuals of *saltator* also tend to be smaller than those of *picticornis*.

No previously unrecorded specimens have been seen.

Strangalia sallaei (Bates)

Ophistomis sallaei Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:280.

Strangalia sallaei; Linsley and Chemsak, 1971, Arq. Zool., 21:32.

Female: Form moderately robust, elytra attentuated; color pale orange-yellow, parts of head, antennae except segments 8 to 10, two pronotal stripes and parts of legs and underside black, elytra with a broad arcuate brownish humeral band on each side, two black spots at middle and a broad dark longitudinal band postmedially to apex, suture narrowly dark. Pronotum with disk densely, confluently punctate, densely pubescent, abdomen glabrous, apex of last sternite medially impressed, angles not produced; apex of last tergite emarginate. Length, 18 mm.

Male: Unknown.

Type locality: Mexico

The coloration is similar to that of *S. picticornis* but the densely punctate and pubescent pronotum will readily separate *sallaei*.

This species is known only from the type.

Strangalia saltator (Bates)

Ophistomis saltator Bates, 1885, Biologia Centrali-Americana, Coleoptera, 5:281, pl. 20, fig. 6; Chemsak, 1964, Jour. Kansas Entomol. Soc., 40:78.

Strangalia saltator; Linsley and Chemsak, 1971, Arq. Zool., 12:31.

Male: Form slender, strongly attenuated; color yellowish, parts of head, antennae, two discal pronotal stripes, parts of legs and parts of underside black, elytra with two median black spots extending from margins but not to suture, a post median black band, and apices black. Antennae with large, elongate poriferous areas. Pronotum sparsely, transversely punctate, pubescence sparse. Legs with hind tibiae vaguely carinate. Abdomen with last

sternite excavated for most of its length, sides moderately produced, angles strongly dentate; last tergite emarginate at apex, not dentate. Length, 14–16 mm.

Female: Form less attenuated. Abdomen with last sternite impressed medially, angles acute; last tergite sinuate emarginate at apex, not acutely produced. Length, 14 mm.

Type locality: San Feliz, Panama

The shape of the last abdominal sternite and tergite and all black antennae of females distinguish this species from *S. picticornis*.

We have seen no specimens other than the type series.

Strangalia **westcotti**, n. sp.

Male: Form slender, elongate, elytra strongly attentuated; integument, reddish orange, eyes, spot on neck beneath, margins of pronotum narrowly, antennal segments six, seven and part of five, front and tarsi dorsally, part of hind tibiae, and margins of some sternites black, elytra black except for two vaguely pale circumscutellar spots, two yellow antemedian and two yellow median spots, segments 8 to 11 of antennae yellow. Head with front rather short, vaguely, finely punctate, glabrous; vertex finely, confluently punctate, very sparsely pubescent; antennae about as long as elytra, slightly thickening from sixth segment; small poriferous pits present from seventh segment. Pronotum with sides slightly sinuate, apex impressed; disk strongly convex; punctures dense, transverse, confluent; pubescence very short, black, depressed; prosternum glabrous, rugulose; meso- and metasternum minutely, densely punctate, moderately densely pubescent; metasternum with two small, vague tubercles toward apex. Elytra more than three times as long as broad, strongly narrowing before middle; punctures fine, separated; pubescence short, dark, depressed; apices obliquely, shallowly emarginate. Legs slender; hind tibiae slightly arcuate, vaguely carinate at apices. Abdomen extending about two segments beyond elytra; sternites finely, densely punctate at sides, minutely pubescent; last sternite shallowly impressed for 4/5 its length, sides moderately produced at apex. Length, 19 mm.

Holotype male: (California Academy of Sciences) from 20 miles SE Ixtlan del Rio, Nayarit, Mexico, 22 July 1963 (R. L. Westcott).

This species somewhat resembles *S. bicolorella* in appearance and coloration, but may be separated by the tri-colored antennae, more finely punctured and more strongly attenuated elytra, much shorter palpi, and less strongly excavated last abdominal sternite.

We are pleased to name this species for R. L. Westcott who has made his collection available for study.

Strangalia xanthotelas (Bates)

Ophistomis xanthotelas Bates, 1892, Trans. Entomol. Soc. London, 1892: 158, pl. 6, fig. 4; Chemsak, 1964, Jour. Kansas Entomol. Soc., 40:75.

Strangalia xanthotelas; Linsley and Chemsak, 1971, Arq. Zool., 21:33.

Male: Form slender, strongly attentuated; color black, antennae with segments from apex of eighth yellow. Antennae lacking poriferous areas. Pronotum shallowly, rather sparsely punctate. Legs with hind tibiae strongly carinate internally. Abdomen with last sternite deeply excavated over entire length, sides moderately produced, apical angles dentate. Length, 14–16 mm.

Female: Elytra less strongly attentuated. Abdomen with apex of last sternite moderately impressed; last tergite deeply emarginate at apex. Length, 12 mm.

Type locality: Acaquizotla, Guerrero, Mexico

This species is known at present only from the type series.

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BOOK REVIEW

A Field Guide to the Butterflies of the West Indies. Demeter Press; Quadrangle. The N. Y. Times Book Co. (Distributed by Harper & Row). 224 pp. 24 color plates. $12.50. 1976.

This handy volume presents a comprehensive guide to the identification of 292 butterflies throughout the Caribbean area, from southern Florida to Barbados and Trinidad. Actually Trinidad, Aruba, Curacao and Bonaire are not included as this would have more than doubled the number of species listed. The text includes a description of almost all but the rarest species, with notes on size, color, habitat, and where available, developmental stages. A handy distribution table and checklist is included, as well as a concise index of scientific names, common English names, and a short bibliography. Although data on the biology of many tropical butterflies is lacking, the author provided what has been published. The book includes an introduction dealing with the anatomy and life history of butterflies, as well as seasonal variations and geographic variation. A useful glossary of terms is also provided. The book fills a need for a single inexpensive description of all butterflies of the West Indies. It will be welcomed by the amateur as well as the serious professional entomologist.

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Natural History of Insects Living in Inflorescences of Two Species of *Heliconia*

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Abstract: The life histories of eight species of insects which live in the water-filled bracts of *Heliconia wagneriana* and *H. imbricata* are studied. Development times of larval forms are directly correlated with the length of time an inflorescence survives on a plant. Few predators were collected from these inflorescences. It is hypothesized that low predation rates may be important in the evolution of insects living in *Heliconia* inflorescences.

INTRODUCTION

Lowland Costa Rican rainforests contain a variety of plants in the genus *Heliconia* (Musaceae or Heliconeaceae of Smith, 1966). These plants show considerable variations in morphology, size, pollination systems, and habitat preference (Linhart, 1973; Stiles, 1975). Many *Heliconia* species have erect inflorescences which consist of a series of large bracts, each bract containing several flowers. These erect bracts collect and hold water from both rains and transportation processes. Such water-filled bracts of *Heliconia* serve as small aquatic habitats for a variety of organisms. Species of *Paramecium* are common in inflorescences of some *Heliconia* species (Vandermeer et al., 1972). Maguire,

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We dedicate this paper to Donald R. Strong, Jr. who has constantly encouraged our *Heliconia* research.

Belk, and Wells (1968) have shown that protozoan communities in *Heliconia* inflorescences may be fed upon by mosquitoes. This report examines the life histories of the most common insects, excluding mosquitoes, living in the inflorescences of *Heliconia wagneriana* Peters and *Heliconia imbricata* (Kuntze) found on Península de Osa, Costa Rica.

FIELD SITE AND NATURAL HISTORY *HELICONIA* SPECIES

This research was done within a 12 km radius of the Tropical Science Center Field Station near Rincón de Osa, Península de Osa on the Pacific coast of Costa Rica. This is an area of tropical wet forest, the climate, topography, and flora of which have been described by Holdridge et al. (1971). A dry season at the Península de Osa occurs from January through April.

On the Península de Osa, flower buds of *H. wagneriana* begin emerging at the end of December and flowering occurs for the population regularly throughout the dry season until late April. A mature inflorescence has between 4 and 8 pairs of bracts, each bract on an alternate side of the rachis. The length of the water containing portion of the bract is between 55 and 70 mm although an entire bract including the extending tip may be 20 cm. Bract widths are between 24 and 40 mm and the depths between 55 and 65 mm. The bracts contain as much as 6 cc of water. Although this plant grows in the dry season, the bracts are almost always filled with water. Most of the water apparently is the result of plant transportation processes. The only bracts of *H. wagneriana* which we have seen devoid of water (or with little water) have been those located in a single well drained and always sunny (12 hours a day in the dry season) area next to Aeropuerto Rincón. These inflorescences did not contain many insects. Remaining plants at this field site always held water and maintained an insect community.

H. wagneriana grows in relatively sunny areas in forest edges, along road cuts and along stream beds. When flowering, plants produce a new bract pair about each 9 days. Each inflorescence remains on the plant for about 11 weeks and shows little evidence of rotting until senescence.

Heliconia imbricata blooms during the rainy season from June through September. In contrast to *H. wagneriana*, most plants flower synchronously at the beginning of June with only a few inflorescences beginning after that time. At any given time, most of the inflorescences in a locality are of the same age. Inflorescences last on each plant for up to 11 weeks; however, by the eighth week nearly one-half of each inflorescence has rotted. This is again in contrast to *H. wagneriana* whose inflorescences maintain a constant state until shortly before they die. Flowering *H. imbricata* plants produce a new bract pair about once each week.

H. imbricata has small bracts, the lengths of which are between 50 to 70 mm, the widths between 25 and 35 mm and the depths about 30 mm. The water

held in these bracts although not measured, is considerably less than that held by *H. wagneriana.* Mature *H. imbricata* inflorescences carry between 8 and 14 pairs of imbricate bracts. This plant is found along streams or near treefalls (open areas in the forest caused by the death and subsequent falling of a tree) in more shaded areas in the forest. Within the study area, *H. imbricata* was encountered more frequently than *H. wagneriana.* Further information on the gross morphology of these and other *Heliconia* species is available (Smith, 1966; Stiles, 1975).

NATURAL HISTORY OF THE INQUILINE INSECT SPECIES

The life histories of 8 of the common species of insects living in *Heliconia imbricata* and *Heliconia wagneriana* inflorescences were studied in detail. These insects include 6 species whose interactions have been considered elsewhere (Seifert and Seifert, 1976). Observational studies on living clumps of *Heliconia* inflorescences yielded times and location of foraging, oviposition, and movements of the inquiline insects. The length of life cycles of some of the insect species was estimated by culturing insects in the field station.

Population densities of some insect species varied with inflorescence size and season. Several times a month, clumps of inflorescences were located, inflorescences were measured by number of bract pairs, and inflorescences were cut (Seifert, 1975). Each inflorescence was then dissected and the densities of insect species were recorded. Inflorescences were grouped together by number of bracts and separated by months. A Kruskal-Wallis nonparametric analysis of variance was used to determine if the density of each species of insect varied among months. *H. wagneriana* inflorescences ranging in size from 3 through 4 bract pairs and *H. imbricata* inflorescences ranging in size from 5 through 7½ bract pairs were used for this analysis. Both of these classes consisted of 3/16 of all possible size classes. Table 1 lists the median and range of numbers of individual insects per inflorescence by month as well as the *H* value (the Kruskal-Wallis statistic) for each species under study. From that table it can be seen that *Copestylum ernesta*, *Beebeomyia* sp., and *Odontolinus fasciatus* exhibit significant seasonal variation in *H. wagneriana* and that *Quichuana aurata* and *Cephaloleia puncticollis* exhibit seasonal variation in *H. imbricata.*

Litopeltis sp. (Dictyoptera: Blattidae). Nymphs of this cockroach were found in the inflorescences and occasionally in the leaves of *H. imbricata.* Individuals rest during the day within the bracts but forage at night both on the outer and inner surfaces of the bracts, feeding on decaying bract parts and mold growing on the bract tips. *Oothecae* were never found in the inflorescences and thus the length of developmental period was not measured. A Kruskal-Wallis test shows no significant differences of densities among the months tested.

TABLE 1. Median and range of numbers of individual insects per *Heliconia* inflorescence in each of three months.

		June	July	Aug.	*H*
H. imbricata					
Quichuana aurata	Median	20	2	0	
	Range	36	32	56	
					22.286***
Gillisius sp. #1	Median	2	2.5	1.5	
	Range	8	8	10	
					1.242 ns
Merosargus sp.	Median	4	8	4	
	Range	18	40	15	
					1.147 ns
Cephaloleia puncticollis	Median	12.5	8	4	
	Range	23	31	17	
					8.994*
Litopeltis sp.	Median	1	2	0	
	Range	15	18	18	
					1.364 ns
Odontolinus fasciatus	Median	0	0.5	0	
	Range	4	4	3	
					1.617 ns
Beebeomyia sp.	Median	0	1	0.5	
	Range	10	17	4	
					1.844 ns
		Jan.	Feb.	March	*H*
H. wagneriana					
Quichuana aurata	Median	23.5	25	23	
	Range	60	155	47	
					1.912 ns
Gillisius sp. #1	Median	2.5	3	10	
	Range	16	25	28	
					5.521 ns
Copestylum ernesta	Median	1	3	9.5	
	Range	7	27	26	
					11.427***
Beebeomyia sp.	Median	0	1	2	
	Range	1	10	16	
					17.771***
Odontolinus fasciatus	Median	0	0	2.5	
	Range	1	1	9	
					17.427***

Note: The differences in location among ranked counts are tested by the Kruskal-Wallis test, whose adjusted test statistic, *H*, is given in the last column. Statistical significance is indicated as follows: ns = $P > .05$, * = $.05 > P > .01$, ** = $.01 > P > .001$, *** = $P < .001$.

Cephaloleia puncticollis Baly (Coleoptera: Chrysomelidae; Hispinae). This is one of a number of hispine beetles which forage exclusively in *Heliconia*. Unlike most members of this subfamily, which feed on the cylindrically rolled new leaves of a species of *Heliconia*, larvae of this species feed on *Heliconia imbricata* inflorescences and most oviposition occurs in June. Eggs are laid in clusters of from 1 to 6 on the inside of the bracts. Larvae feed by rasping the inside of the

bract and rarely the flower. The larval period lasts about 60 days; pupae are attached directly to the bract and eclose after about 15 days. Densities of *C. puncticollis* larvae varied among months (Table 1).

Gillisius sp. #1 (Coleoptera: Hydrophilidae). This species is the most common beetle found in *Heliconia* inflorescences. It is abundant as an adult in both *H. wagneriana* and *H. imbricata* although the larval forms have not been found. The adult feeds on floral parts by crawling down the outside of the flower into the water. As this is done, an air bubble is trapped on the ventral surface by the hydrofuge hairs. The air bubble aids in buoyancy (if the hydrophilid is dislodged from the flower underwater it quickly bounces to the surface) and may be useful in respiration (Lanciani, 1970). *Gillisius* has been observed remaining in the water for as long as 3½ minutes but most underwater forays are between 30 and 60 seconds. When not feeding, this beetle rests above the water on the inside of the bract near the rachis. Copulation, but not oviposition, has been observed in the inflorescences. Although we have not observed *Gillisius* larvae in these plants, P. J. Spangler has informed us that he has obtained a few *Gillisius* larvae from *Heliconia* inflorescences in Ecuador. The common occurrence of adult *Gillisius* in *Heliconia* and the rarity of their larvae in *Heliconia* lead us to believe the main larval habitats are not *Heliconia* inflorescences. Density variation of adults among months was not significant (Table 1). During the non-blooming season these beetles can be found in the young leaves of *Heliconia*.

Gillisius is a genus with few described members (P. J. Spangler, personal communication). A second species of *Gillisius* is found occasionally in these *Heliconia* inflorescences, and we have observed similar species in Venezuelan *Heliconia*.

Odontolinus fasciatus Sharp (Coleoptera: Staphylinidae). This beetle is occasionally found as an adult in both species of *Heliconia*. It walks down the flower or the inside of the bract into the water, captures mosquito larvae and returns above the water to devour them. It is not uncommon for *O. fasciatus* to continue foraging until several mosquito larvae have been eaten. Laboratory observations indicate that this staphylinid will eat newly emerged larvae of the flies *Quichuana aurata* and *Beebeomyia*, both of which are common in these *Heliconia*. However, newly emerged larvae of these fly species are usually found in bracts which are only very slightly open and which would be difficult for *Odontolinus fasciatus* to enter. Population densities of *O. fasciatus* vary among months in *H. wagneriana*. *O. fasciatus* is infrequently found in *H. imbricata* (Table 1).

Quichuana aurata Walker (= *Q. picadoi* Knab in Seifert and Seifert, 1976). This insect is found in both *H. wagneriana* and *H. imbricata*. Oviposition occurs throughout the flowering season of *H. wagneriana*. Females choose as an oviposition site bracts which are slightly opened. The female lands and extends

a three pronged ovipositor into the inside of the bract. A female will reject a bract if previous eggs have been laid there (including both hatched and unhatched eggs) although she may oviposit in several inflorescences in a single clump. The number of eggs laid in one clutch ranges from 8 to 32. *Q. aurata* lays eggs in *H. wagneriana* from January to April, as successive bracts develop throughout this period. Due to the continual oviposition by adults on the young bracts, several larval size classes, ranging from newly hatched to last instar can be found in a single inflorescence. Larvae hatch 2 days after oviposition and feed for about 45 days on floral parts, nectar, and detritus on the floor of the bract. Larval densities show no significant difference among months in *H. wagneriana* (Table 1).

Pupal life lasts about 8 days and eclosion has only been observed in the morning. Laboratory work has shown that if newly emerged flies are not allowed to dry their wings immediately after eclosion, they will be unable to fly. The morning eclosion of *Q. aurata* pupae is probably a response to afternoon rains in the wet season.

The natural history of *Q. aurata* is somewhat different in *H. imbricata*. Oviposition on *H. imbricata* occurs only when the inflorescence is a small bud and primarily during the beginning of the flowering season. This may be due to the relatively quick rotting of *H. imbricata* inflorescences. Correspondingly, densities of *Q. aurata* vary among months in *H. imbricata* (Table 1).

The larval food sources of *Q. aurata* are the inflorescences of *Heliconia wagneriana* and *H. imbricata*. We did not find *Quichuana* larvae in non-*Heliconia* water-filled plants (such as bromeliads) on the Península de Osa. Hence, there appear to be 6 months during each year (May and August through December) when populations of this insect consist entirely of adults. However, when *H. wagneriana* begins to bloom in January, the larval populations are as high as later in the season (Table 1), when reproduction from adults which matured in the previous month occurs, and when adult populations should be at their highest. Since no change in larval densities of *Q. aurata* occurs in *H. wagneriana*, the adult population is presumably large enough to maintain the larval population at maximum densities throughout the year.

A second morphological form (provisional number 7627 of F. C. Thompson) of *Quichuana* exists in these Costa Rican *Heliconia*. The morphological structure of the adults of *Q. aurata* and the second form are identical except that *Q. aurata* exhibits bright golden metallic pile on the body while the pile from the second form is grey. (The taxonomic status of this form will be discussed by F. C. Thompson.)

Larvae of *Q. aurata* are occasionally found in a third species of *Heliconia*, *H. latispatha* Benth. on the Península de Osa. In the laboratory, we have reared larvae to adults feeding them only *H. latispatha*. However, in the field only one pupa of *Quichuana* has been found in this species of *Heliconia*. Skutch found

Table 2. Summary of natural histories of common insect species inhabiting two species of *Heliconia* inflorescences.

Insect species	*Heliconia* sp. inhabited	Insect stage	Food	Oviposition site	Developmental period	Dependency on *Heliconia* inflorescences
Litopeltis sp.	*imbricata*	nymph	outside of bracts	unknown	unknown	great
Cephaloleia puncticollis	*imbricata*	larva	inside of bracts	bracts	75 days	great
Gillisius sp. #1	*wagneriana imbricata*	adult	detritus, flower parts	unknown	unknown	great
Odontolinus fasciatus	*wagneriana imbricata*	adult	mosquito larvae	unknown	unknown	some
Quichuana aurata	*wagneriana imbricata*	larva	flower parts, detritus, nectar	bract tip	55 days	great
Copestylum ernesta	*wagneriana*	larva	flower parts, nectar	flowers	60 days	great
Merosargus sp.	*imbricata*	larva	flower parts, rotting flower parts, detritus	rachis	70 days	great
Beebeomyia sp.	*wagneriana imbricata*	larva	flower parts	rachis	unknown	unknown

Eristalis (probably *Quichuana*) in *H. bihai* L. (= *wagneriana*) in Panama (1933) and has noted its presence in Costa Rica (1971). We have seen *Quichuana* larvae in Colombian and Venezuelan species of *Heliconia*, and similar species have been found sporadically in Jamaican bromeliads (Laessle, 1961).

Copestylum ernesta (Curran) [= *C.* cf. *obscurior* (Curran) in Seifert and Seifert, 1976] (Diptera: Syrphidae). This fly breeds almost entirely in *H. wagneriana*. Maturation from small larvae to adults requires 50 to 60 days and larval densities greatly increase from January to March (Table 1). Foraging habitats include nectar feeding and consumption of detritus. Since this organism is found only rarely in *H. imbricata*, this fly either lives as an adult from May through December or as larvae on other resources during that period.

Merosargus sp. (Diptera: Stratiomyidae). This undescribed species of *Merosargus* is abundant in *Heliconia imbricata* but absent from *H. wagneriana*. Copulating pairs of adults are seen resting on *Heliconia* leaves or on vines, stems, or other parts of plants near *Heliconia* clumps. Eggs are laid on the rachis below the lowest bract. The leathery larvae feed on rotting floral parts and detritus and maturation from egg to adult takes from 60 to 70 days. Densities in small inflorescences do not change during the months of *H. imbricata* flowering (Table 1). Since *Merosargus* larvae are abundant in *H. imbricata* but absent from other environments examined, including non-*Heliconia* habitats, it is possible that an adult population is maintained for 8 months between reproductive periods. (M. T. James will describe this species.)

In *H. wagneriana*, the congener, *M. gowdeyi* Curran is occasionally found. The adults of this *Merosargus* are commonly seen courting and copulating near various species of *Heliconia*, but the larvae may be more closely associated with *H. latispatha* than with either of the species of *Heliconia* under study.

Beebeomyia sp. (Diptera: Richardiidae). *Beebeomyia* larvae feed on both *H. imbricata* and *H. wagneriana*. Flower parts, particularly the petals, and nectar seem to be the main food source. Oviposition occurs on the rachis or inside the bract near the juncture of the rachis and bract. Larvae occasionally are found in *H. latispatha* and adults are seen copulating there as well as near *H. imbricata* and *H. wagneriana*. Densities increase from January to March in *H. wagneriana* but remain constant in *H. imbricata*. The development time was not measured. (B. Steyskal will describe this species.)

Table 2 presents a summary of the natural histories of the insects under study.

DISCUSSION

Few organisms prey on insects which live in *Heilconia* inflorescences. One insect not discussed above, the earwig *Carcinophora americana* (Beauvois) (Dermaptera: Carcinophoridae) is found rarely in *Heliconia* inflorescences.

Adults of this species have been maintained in the field station for over 3 months and will feed on most insect species found in the inflorescences. Thus, a single inflorescence could support an adult *C. americana* for at least several weeks. However, this earwig occurs so infrequently in the inflorescences that it is unlikely to be an important predator. In the field station, the staphylinid beetle, *Odontolinus fasciatus* (Sharp), has been seen to feed only on mosquitoes. We have occasionally seen spiders waiting on the edges of the bracts and capturing adult *Quichuana aurata*. Similarly, one anole was seen feeding on an adult *Q. aurata*. Predation does not seem to be important in the natural history of these insects while they live in the inflorescences. The relative low importance of predation has been noted in mosquito populations living in pitcher plants (Istock et al., 1975) as well as among hispine beetles living in *Heliconia* leaves (D. R. Strong, personal communication).

That this system is largely predator free may be important in the evolution of these insect species. Insects which live as larvae in *Heliconia* inflorescences have larval and pupal stages that are close to the length of time that each inflorescence survives. The length of development time of *Cephaloleia puncticollis* is between one and two weeks less than the length of time that *H. imbricata* inflorescences go from bud to complete rotting. Pupae of this species are often found in inflorescences in which substantial rotting has occurred. *Merosargus* sp. larvae and pupae spend nearly as much time in the inflorescences as do larvae of *C. puncticollis*. Development times of *Q. aurata* seem to be geared to the time at which *H. imbricata* begins to rot, rather than the complete rotting of the inflorescence.

Larval forms can maintain themselves in the bracts no longer than the time from bud emergence to flower rotting. Selection must favor eclosion to adult forms before the death of the inflorescence. As Williams (1966) has pointed out, selection could initially favor organisms which reproduce as quickly as possible. Typically, selection on energetic constraints limits reproduction so that reproduction occurs when the probability of success is maximized. Reproductive success of insects in *Heliconia* inflorescences may involve maximizing the amount of time larvae stay in inflorescences. Low levels of predation in inflorescences may allow larvae long development times, particularly if adult forms or forms moving between inflorescences are subjected to high mortality. Decreasing development time would not be an optimal strategy. For insects living in *H. imbricata*, individuals which emerge midway through the life of an inflorescence would be exposed to an environment in which most of the inflorescences are relatively old. In such a case, rotting of the inflorescence would occur before complete development of the insects. Alternatively, extending the development time in a predator free habitat, such as the inflorescences, would lead to greater probability of survival until the next blooming season and a subsequent greater probability of a reproductive success. Thus, selection maximizing time spent in

an inflorescence may occur for insects in *H. imbricata* inflorescences. Since *H. wagneriana* blooming is much more staggered temporally than is *H. imbricata* blooming, adults emerging from *H. wagneriana* inflorescences often will be able to find young inflorescences for oviposition. Maximizing life time in the inflorescence may be a response to selection pressures primarily associated with *H. imbricata*. Counteracting selection pressures occur for insects living in *Heliconia* inflorescences: selection to maximize development time will be counteracted by selection to reduce development time to coincide with the length of life of the inflorescence.

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Sex Ratio of Adult Head Lice[1] Under Crowded Conditions[2]

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Abstract: The shortened life expectancies of female head lice, *Pediculus humanus capitis* DeGr., due to increased copulations by males when overcrowded, was examined in natural and reared louse populations. Natural populations were too small to verify if a detrimental influence upon females by males does occur, while the number of reared females was not significantly reduced in the denser populations indicating female longevity does not decrease when overcrowded. Results from individually isolating newly emerged females with a number of like males showed the former survived a considerably shorter time than their normal life expectancies. The shortened lives of these females was attributed to their not being fully sclerotized prior to copulating, causing injury and death, and not as the result of frequent copulations by males.

The ratio of adult male head lice, *Pediculus humanus capitis* DeGr., to females on lightly and heavily infested individuals was examined in several studies. Examination of complete crops of hair of 125 infested male prisoners from Colombo, Ceylon, showed that those (49) with 1–2 adult lice had 70% females; those (13) with 26–100 adults bore 50%; while those (9) with 101 or more yielded 40% females (Buxton 1937). This significant decrease of females was attributed to more frequent copulations by males in the denser populations, which injured females and shortened their lives, thus reducing their numbers (Buxton 1941). Buxton believed that a difference in female mortality begins when the number of adults per head is between 25 and 100 and is greatly increased when the total exceeds 100. Crops of infested hair from Kakamega, Kenya, and from Lagos, Nigeria, were also examined which yielded no decrease of females on those with higher louse densities (Buxton 1941).

In another study, head lice collected from 67 infested refugees revealed that those (37) with 1–50 adults harbored 75% females; those (7) with 51–100 adults yielded 76%; those (20) with 101–500 had 74%; two individuals with 501–1000 embodied 79%; while one infested with 1434 adults yielded 83% females (Roy and Ghosh 1944). These findings thus show that females were not reduced under more crowded conditions in contrast to the above studies.

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[1] Anoplura:Pediculidae.

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In the present study, the detrimental influence of male head lice upon females under crowded conditions is examined in natural and reared populations.

METHODS

The sex ratio of adult head lice in natural populations was studied by collecting crawling stages from 93 Tucson school children. Students were thoroughly examined to ascertain that all or the majority of lice were removed. The number and sex of adults was then determined for each host individual examined.

The female/male ratio of reared lice was examined by counting various generations of a colony maintained in a modified pill bottle (Lang and Roan 1975). The colony was initiated with three males and seven females collected from an individual and terminated at F_{27}.

The longevity of female lice in the presence of males was examined by isolating a newly emerged female with two newly emerged males in a rearing container similar to the one used for the parent stock. This procedure was repeated 10 times using different lice.

RESULTS AND DISCUSSION

Forty-six of the 93 infested children yielded adult lice. Results showed that 29 individuals, each with 1–5 adults, yielded 69% females; those (11) with 6–10 had 66%; those (5) with 11–15 had 63%; while one with 18 adults bore 64% females. Chi-square analysis showed no significant decline of females on individuals with higher adult numbers. The low adult numbers on these individuals, however, could not adequately verify if higher louse densities do have a detrimental influence upon females.

The percentage of female lice determined for different reared generations in a colony is depicted in Table 1. The lack of a significant decrease of females in the denser generations examined, particularly for F_{20} and F_{27} which were very overcrowded in the rearing container, indicates that denser populations do not yield a lower number of females due to increased copulations.

Individual female lice kept with males survived on the average 14 days, while the normal life expectancies for newly emerged females isolated by themselves averaged 30 days (Lang 1975). Duncan's Multiple Range test showed a significant difference (5% level) for survival periods of females kept with males, compared to those isolated. A similar experiment was conducted by Buxton (1940) employing body lice, *P. h. humanus* Linn. His results showed that mean life expectancies for newly emerged females, individually isolated with 4 to 18 newly emerged males, was about 10 days. He also found that life expectancies for mature females, individually kept with a similar number of males, did not appear to be reduced.

The premature deaths of newly emerged females isolated with males may be the result of their not being fully sclerotized prior to copulating, so that injury

Table 1. Percentage of female head lice, *Pediculus humanus capitis*, occurring in reared generations.

Generation	No. Adults	Females (%)[1]
F_3	112	68
F_5	169	65
F_{15}	210	61
F_{20}	430	62
F_{27}	326	58

[1] Chi-square value = 2.172 with 4 degrees of freedom, while expected Chi-square value = 9.488.

and death occurs. This is supported by Buxton's (1940) findings for the apparently normal longevities of mature females kept with males.

Buxton (1941) concluded that the sex ratio of lice is evidently determined by the chromosomes alone and found no evidence that any environmental factor effects sex ratio except when a female encounters a male very frequently. Roy and Ghosh (1944), however, disagreed with this latter statement since they found no decline of females on those moderately or even heavily infested, even though the majority of these individuals supported very heavy infestations.

Results from the present study concerning reared populations, some of which were very overcrowded, also refute Buxton's (1941) findings that higher louse densities decrease female numbers due to more frequent copulations. It thus appears that chromosomes alone do determine the ratio of sexes in head louse populations, although Buxton's (1941) Colombo study, showing a significant decrease of females from lightly to heavily infested individuals, is the only data found disagreeing with this concept.

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Three New Achipterids from the Catskills of New York State, U.S.A. (*Acari*; *Cryptostigmata*; *Oribatei*; *Oribatelloidea*; *Achipteriidae*)

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Abstract: *Parachipteria* **travéi**, *Achipteria* **catskillensis** and *Achipteria* **clarencei** from the Catskill Mountains of New York State are described and figured and comparisons in size and morphological features are made with described species of similar features.

The descriptions of new achipterids from the Smoky Mountains of North Carolina led to further studies of specimens of the group from the Catskills of New York State. Descriptions and figures of three new species follow.

Parachipteria **travéi**[1] n. sp.

Genus *Parachipteria* Van Der Hammen 1952 is characterized by the presence of large pteromorphs extending to near the tip of the rostrum and by a notogaster with distinct areae porose (Balogh 1972).

Type. Oribata punctata (Nicolet 1855).

Description of *Parachipteria* **travéi** n. sp.

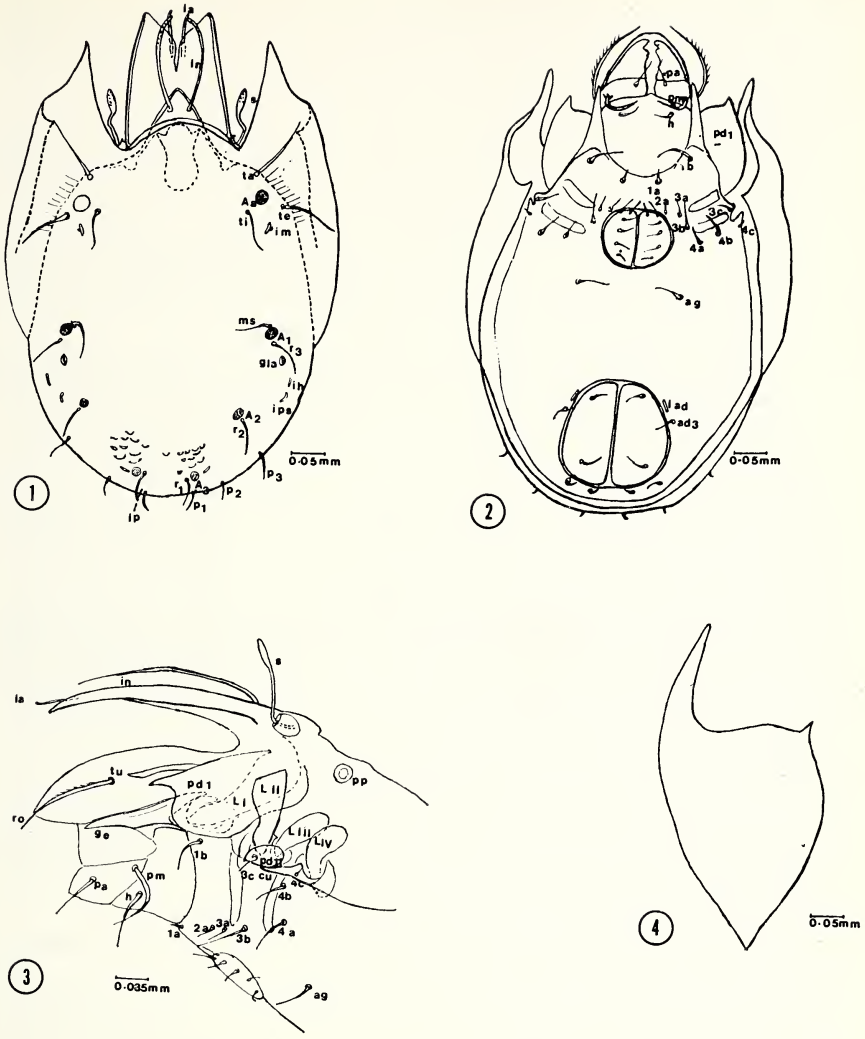
Color. Dark brown to black with the legs, the tips of the lamellae, and the anterior parts of the pteromorphs amber. (It is necessary to bleach specimens for study. Best results were obtained from specimens fixed in modified Berlese fluid, bleached for several days in a 10% solution of NaOH, washed and then examined in lactic acid.)

Size. Length—0.779 mm mean for 6 specimens. Range 0.760 mm to 0.825 mm. Breadth—0.579 mm mean for 6 specimens. Range 0.550 mm to 0.605 mm. Depth—0.510 mm mean for 6 specimens. Range 0.451 mm to 0.561 mm.

Prodorsum. The lamellae are long and broad and fused on the midline for less than a third their length. The outer (lateral) cuspis is much longer than the median cuspis. The lamellar setae are short, rough and pointed extending beyond the long lateral cusp. They follow the contour of the lamellae. They are shorter than the lamellae when seen in lateral view (fig. 3). The pedicel of the sensillus bends laterad from the brothridium, then following an outward curve projects forward ending in a head which is slightly rough and about twice the thickness of the pedicel. In lateral view the head of the sensillus is narrow.

Notogaster (fig. 1). In moving the cover glass in the study of specimens in lactic acid the

[1] *Parachipteria travéi* is named for Dr. J. Travé whose descriptions and figures of *Parachipteria petiti* and *Pseudochipteria magna* are sufficiently complete to serve as models for future work.



Figs. 1–4. *Parachipteria travéi* n. sp. 1. Dorsal view. 2. Ventral view. 3. Ventral view of anterior end. 4. Lateral view of right pteromorph.

notogaster is easily separated from the body. Removal of the notogaster makes easier a study of the gnathosoma in lateral view and makes for greater ease and accuracy in the study of the legs. The areae porosae are distinct, and rounded or oval in shape. A distinct lenticulus is present. There are ten notogastral setae. Seta ms is very close to or actually in contact with porose area A_1 (fig. 1). The lyrifissures are typical.

Ventral surface (fig. 2). The setae pm named following Grandjean (1936) for *Bdella* sp. is thick and curved originating from a distinct protuberance on the prementum, the "adoral

sclerite" of Krantz (1971) or "les pieces maxillocoxales" of Grandjean. An apical tooth is present on the lateral tip of pedotectum 1. The epimeral setae are as follows: 1a, 1b; 2a; 3a, 3b and 3c; 4a, 4b and 4c. Setae 2a and 3a are small and equal in length; seta 3b is twice the length of 2a and 3a. These three setae are clustered close to one another. Seta 4c is very small. Seta 1c is not present.

The genital setae are typical for the genus. Setae g_4 and g_5 are only slightly farther apart than any of the other adjacent setae. Lyrifissure iad is anterior to adanal seta ad_3 and close against the border of the anal plate.

Lateral view (fig. 3). The pteromorphs are broad with a pronounced ventral spine on the margin of each (fig. 4). The basal parts of the legs are represented in figure 3 to show the position of the tutorium and pedotectums 1 and 11 relative to the legs. A porose area, pp, is present under the pteromorph. The tutorium has no free tip.

Legs. The projection of legs 1 and 11 between the lamellae and the rostrum makes it very difficult to determine the nature of the structures present and to work out the chaetotaxy of the legs. The chaetotaxy is quite similar to that of *P. savagei* (Nevin, 1976).

Setal formulae. trochanters 1-1-2-1; femora 5-5-3-2; genua 3-3-1-1; tibiae 4-4-3-3; tarsi 19-15-15-12.

Solenidial formulae. genua 1-1-1-1; tibiae 2-1-1-1; tarsi 2-2-0-0. Seta s of tarsus 11 is thick, branched and quite conspicuous.

Discussion. Parachipteria travéi is slightly larger than *Pseudochipteria magna* (Sellnick) but in general is in the same size range so that it has probably been confused with *P. magna* in this country. It is only by the very exact description and figures of *P. magna* by Travé (1960) that one is assured of differences. The chief differences between *Parachipteria travéi* and *Pseudochipteria magna* are:

1. the presence of distinct porose areas in the notogaster of *P. travéi.*
2. the head of the sensillus of *P. travéi* is almost smooth and less truncated at the tip than in *P. magna.*
3. seta pm is heavy and curved, projecting from a protuberance from the maxillocoxal plate in *P. travéi.*
4. epimeral seta, 1c, and lateral seta, ex, are absent in *P. travéi.*
5. the spine on the ventral margin of the pteromorph is much larger in *P. travéi* than in *P. magna.*

The tutorium of *P. travéi* lacks the lateral spine shown by Van Der Hammen (1952) for *P. willmanni.* The porose areas while distinct in *P. travéi* are not as large as those of *P. savagei* Nevin (1976).

Type locality. The type locality for all three species described was a strip of about 30 feet long along the Goulds-Fishes Eddy highway and approximately one mile north of the village of Fishes Eddy, Delaware County, New York. The area nearest the ditch was wet and supported growths of liverworts and spagnum moss. Close up the banks were species of fern mosses, then *Polytricum* and bracken ferns. Collections were made from specific microenvironments but there was such an overlap of species within these environments that no separate account within each microenvironment was attempted.

Type specimens were collected on August 16, 1975. Collections from the same area and containing the same species had been made in the summers of 1973 and 1974.

Holotypes and a few paratypes of each new species will be deposited in the New York

State Museum, Albany, New York. Additional paratypes will be deposited in the U.S. National Museum.

Achipteria **catskillensis** n. sp.

Genus *Achipteria* Berlese 1885.

Type species. Achipteria coleopterata (Linné, 1758) Van Der Hammen (1952).

Generic characters. Achipterids with large pteromorphs extending to near the tips of the rostrum; notogaster with sacculi.

Description of *Achipteria catskillensis* n. sp.

Color. Light reddish brown. It is not necessary to bleach specimens for study.

Size. Balsam mounts—mean for 13 specimens L—0.445 mm; Range 0.407 mm to 0.462 mm. W—0.326 mm; Range 0.297–0.374 mm.

Temporary mounts in lactic acid mean for 12 specimens; L—0.441 mm; Range 0.407 mm to 0.473 mm. W—0.289 mm; Range 0.253 mm to 0.352 mm.

Prodorsum (fig. 5). Lamellae fuse for a short distance on the midline. The cusps of the lamellae are nearly equal in length. Lamellar setae are smooth, pointed and bent ventrad at their tips. They originate from the ventral surface of the inner cusp near the point of fusion of the lamellae along the midline. The interlamellar setae are smooth as are both the heads and pedicels of the sensilli. The head of the sensillus is flat and pointed in dorsal view. The sensilli curve mesad over the pronotum extending to a point close to the point of fusion of the lamellae. They do not meet on the midline.

Notogaster (figs. 5, 7, and 8). A lenticulus is lacking. Sacculi are well developed. There are ten pairs of notogastral setae. Setae ta and te are at least twice as long as seta ti. Seta r_3 is close to saccule S_1 while seta ms is more than five times the distance from S_1.

Ventral surface (fig. 6). Seta pm is a heavy seta but is not U-shaped. Pedotectum 1 lacks an apical denticle. Epimeral setae 1c and 4c are lacking. Setae 2a and 2b are very small. Adanal seta ad_3 is very close to the posterior end of the lyrifissure iad.

Lateral view (fig. 8). The pteromorphs lack a ventral spine. The custodium is rather blunt.

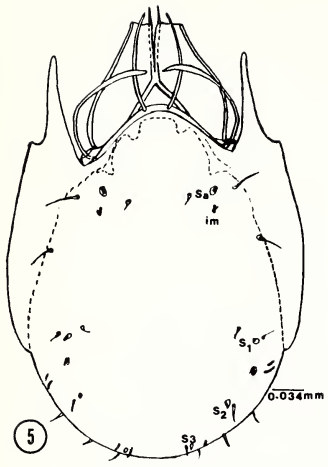
Legs. Chaetotaxy.

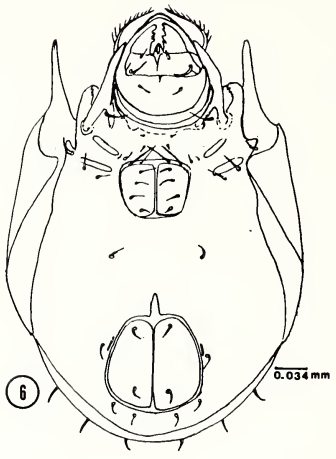
Setal formulae. trochanters 1-1-2-1; femora 5-5-3-2; genua 3-3-1-1; tibiae 4-4-3-3; tarsi 20-15-15-12.

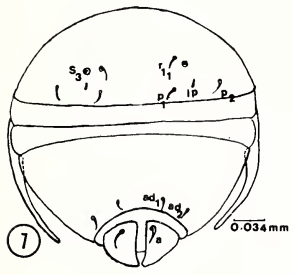
Solenidial formulae. genua 1-1-1-1; tibiae 2-1-1-1; tarsi 2-2-0-0. The spur on genua 1 and 11 is of moderate length and thickness.

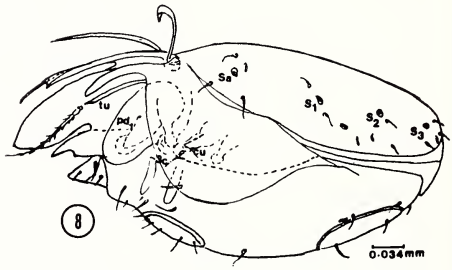
Discussion. The presence of a lenticulus is given by Balogh (1972) as one characteristic of the genus *Achipteria.* This feature seems to hold for most of the species but not for *A. catskillensis.* There is a lighter area in the position for a lenticulus but no distinct lenticulus. The tutorium does not show in most specimens. This is probably due to the fact that the notogaster and pteromorphs are not readily removed and that leg 1 extends over this area. The spurs on genua 1 and 11 are proportionally smaller than in related species and genera.

Achipteria catskillensis is smaller than other species of the genus. It averages smaller than *A. italica* (Oudemans 1913). Oudemans (1927) gives measurements for *A. italica* of 0.488 mm by 0.370 mm; Travé (1960) gives lengths of 0.490 mm to 0.580 mm. *A. catskillensis* is readily separated from *A. italica* of Oudemans by the sensillus which bends mesad over the









FIGS. 5–8. *Achipteria catskillensis* n. sp. 5. Dorsal view. 6. Ventral view. 7. Rear view. 8. Lateral view.

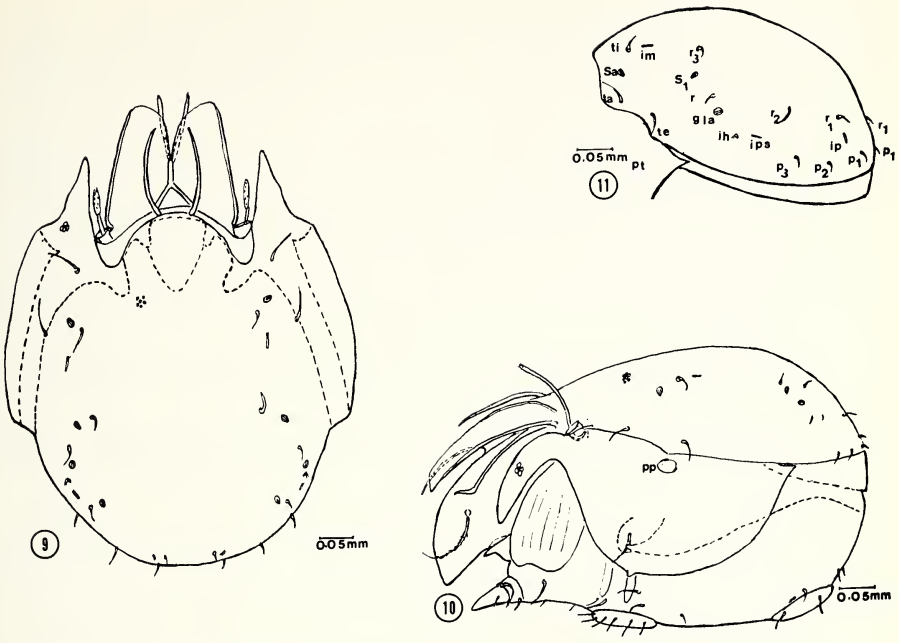
prodorsum while in *A. italica* the much shorter sensillus projects forward. The sensillus of *A. catskillensis* appears similar to that of Sellnick's *Notaspis bellus*. Sellnick gives the size as 0.395 mm by 0.286 mm. This is smaller than *A. catskillensis*. But according to Van Der Hammen (1952) *N. bellus* of Sellnick becomes *Parachipteria bella* (Sellnick 1913) because of the presence of distinct porose areas on the notogaster. Travé (1960) agrees with this classification. *A. catskillensis* possesses distinct notogastral sacculi.

The number of setae (20) for tarsus 1 of *Achipteria catskillensis* agrees with the numbers given by Travé for *Parachipteria petiti* and for *Pseudochipteria magna* but differs from figures given for *Parachipteria savagei* Nevin (1976) and for *Parachipteria heintoogensis* Nevin (in preparation).

Achipteria **clarencei** n. sp.

(Figures 9–11)

Color. Reddish brown to amber with the legs, the apices of the lamellae and the anterior third of the pteromorphs light amber.



Figs. 9–11. *Achipteria clarencei* n. sp. 9. Dorsal view. 10. Dorsal view. 11. Notogaster at angle to show setae.

Size. L—0.664 mm mean for 7 specimens. Range 0.635 mm to 0.693 mm. W—0.522 mm mean for 7 specimens. Range 0.473 mm to 0.561 mm.

Integument. The cuticula particularly that of the pteromorphs and the dorsal surface of the lamellae is coarsely punctate. The cuticula of other parts of the body is more finely punctate.

Prodorsum. The lamellae are fused for a short distance (measured at 0.032 mm in one specimen), then separate. The medial margin of each lamella is slightly shorter than the outer and rounds out to it. In many specimens as seen in dorsal view the lamellae appear to be truncated at their tips. The smooth lamellar setae originate on the ventral surface of the lamellae along the mesial line at a point about halfway between the point of fusion of the lamellae and the apices of the lamellae. A thickening extends from the point of origin of each lamellar seta to the point of fusion of the lamellae. The interlamellar setae are also smooth. They are fairly short not reaching to the tip of the rostrum. Both the head and the pedicel of the sensillus are spinous. The sensilli are short. They extend forward between the legs and the gnathosome proper.

Notogaster. A triangular shaped lenticulus with the base along the anterior margin of the notogaster shows in dark colored specimens. In light colored specimens and in some cleared specimens the lenticulus may not show. There are ten pairs of notogastral setae, all short for achipterids. Setae ta and te are longer than the other notogastral setae. The other notogastral setae are barely visible under 100× magnification. Sacculi Sa, S_1 and S_2 are present but are quite indistinct. Sacculus S_3 could not be distinguished in any specimen. The

arrangement of certain notogastral setae in reference to the position of the sacculi is specific. Seta ms is mesad to sacculus S_1. Seta r_2 is posterior and lateral to S_1. The distance of seta r_2 from S_1 is double the distance of seta ms from the same sacculus. Sacculus S_2 is small and quite indistinct. The other setae and fissures are typical of achipterids.

Ventral surface. Seta pm is large and curved. Of the epimeral setae 1b appears unusually long, setae 1b, 3a, 3c, 4a and 4b are of about equal lengths, setae 1a, 2a and 3b are very small. Setae 3a and 4c are lacking.

The genital, aggenital, adanal and anal setae are normal for the genus. Adanal seta ad_3 is located opposite the midpoint of the longitudinal axis of the anal plate. Lyrifissure iad is adjacent to the margin of the anal plate at a point one third the distance back from the anterior border of the plate. Seta ad_3 is located opposite the midpoint of the longitudinal axis of the anal plate.

Lateral view. The tutorium has a short free tip. Pedotectum 1 lacks a spine. The pteromorphs possess a denticle on the midventral margin.

Legs. Setal formulae. trochanters 1-1-2-1; femora 5-5-3-2; genua 3-3-1-1; tibiae 4-4-3-3; tarsi 20-15-15-12.

Solenidial formulae. genua 1-1-1-1; tibiae 2-1-1-1; tarsi 2-2-1-0.

Discussion. Achipteria clarencei is a member of the genus *Achipteria* but because of the absence of sacculus S_3 and the poor development of the other notogastral sacculi the species seems to be intermediate between the genus *Achipteria* and *Pseudochipteria.*

The presence of a punctated or granular cuticula is definitely a characteristic of the new species, but the degree of punctation in separating species is a valid taxonomic feature only when like colored and like treated specimens are compared. The cuticular granularity is pronounced in untreated dark specimens of *A. clarencei.*

Staining with alcoholic picric acid makes easier the task of identification of the setae of the legs in working out the setal formulae.

Achipteria sellnicki Van Der Hammen 1952 and *Achipteria oudemansi* Van Der Hammen 1952 are in the size range with *A. clarencei.* Both of the above species bear a denticle on pedotectum 1. The denticle is curved in *A. sellnicki,* straight in *A. oudemansi.* The absence of a denticle on pedotectum 1 separated *A. clarencei* not only from the above species but also from *A. nitens* and from *Pseudochipteria magna* (Sellnick). The size of *A. nitens* as given by Van Der Hammen (1952) as 0.700 mm to 0.780 mm in length, by 0.540 mm to 0.560 mm in breadth, also differentiates this species from the new species. Van Der Hammen described the notogastrel setae of *A. nitens* as long "especially, the two pairs near the pteromorphae." The notogastral setae of *A. clarencei* are short. The tips of the lamellae are rounded in *A. clarencei* in contrast to the long pointed outer cusp of the lamellae in *A. oudemansi.*

In addition to the three new species of achipterids several specimens of *Dentachipteria ringwoodensis* and a single specimen of *Dentachipteria highlandensis* were collected at the location mentioned above. *Dentachipteria ringwoodensis* appears to be a widespread and common species and should be considered the type species for the genus. This species from the Catskill region appears to be more variable than the specimens originally described from Ringwood, New York. Most specimens were black with only the legs and the apices of the lamellae amber colored. Many specimens were found with fewer than seven denticles on the pteromorphs. Among the originally described speci-

mens the number of denticles varied from seven to twenty-one. The finding of another specimen of *D. highlandensis* very distinct from *D. ringwoodensis* confirms the former as a valid species.

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BOOK REVIEW

Moths of Australia. Bernard D'Abrera. 1974. Lansdowne Press, Melbourne. 85 pp., many color and a few black and white illustrations, $12.95 (Australian).

This small book includes material of the chief families of Australian moths, illustrated by over 300 species. A good many families, especially of obscure microlepidoptera, are not included. The species included were chosen because of their commonness, striking appearances or economic importance, or because they have some special interests. The illustrations are excellent. Most are of set specimens, but there are numbers of the extremely fine photographs that the author is noted for, of living individuals. A number of excellent larval photographs are included. A lengthy preliminary section covers in a simple way moth structures and life histories, scientific names and classification, and directions and diagrams for dealing with specimens. We like the author's emphasis on rearing moths instead of merely collecting them. The text portions contain many interesting facts about habits and life histories. All in all, this is a worthwhile book for beginners, and should do much to interest young people in particular—by no means only in Australia.

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American Museum of Natural History

BOOK REVIEW

Invertebrate Immunity. Mechanisms of Invertebrate Vector-Parasite Relations. Karl Maramorosch and Robert E. Shope, Eds. Academic Press, Inc. New York, 1975. 365 pp., illustrated. $16.50.

Invertebrate defense mechanisms is a relatively newly developed area of research, with much yet to be learned. This volume, which has been prepared from a workshop on invertebrate defense mechanisms sponsored by the National Institutes of Health and held in Bethesda Maryland April 17 and 18, 1974, makes an important and unique contribution by bringing together for the first time important papers by the leading researchers in this fascinating area. It is a stimulating volume, in that it identifies as many questions about invertebrate immunology and defense factors as it does in presenting research data. In fact, the editors state in the preface that "The authors were urged to bring out imaginative and provocative hypotheses and to suggest experimental approaches which might be applied to solutions".

The book is organized into four general areas: (1) Invertebrate gut as a barrier to invading parasites, (2) Analysis of invertebrate immunity, (3) Hemolymph components in invertebrate immunity, and (4) Vector destruction. Each section contains a short summary paper of about one page, which presents an overview of that section unifying the subject matter in an effective way by focusing the readers attention on the questions and problems emphasized in each of the chapters.

The papers are largely reviews of the particular subject brought up to date with original observations and data. This approach presents the reader with a very timely view of the subject matter, which I found particularly valuable. The illustrations are good and the organization attractive.

I enthusiastically recommend this volume as an invaluable reference to those interested in the area of invertebrate immunity, whether in teaching or research, and especially to the student for the presentation of a new and exciting area of invertebrate biology. The editors are to be congratulated for bringing this volume to such quick completion-barely over a year from conference to publication! Considering this accomplishment, the few typographical and other errors appear insignificant.

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Terrestrial Mites of New York. V- Tarsonemidae[1]

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Abstract: Twenty-one species of tarsonemid mites are reported from New York, of which 11 are described and figured as new: *Steneotarsonemus* **oconnori**, *Tarsonemus* **ascitus**, *T.* **dubius**, *T.* **imitatus**, *T.* **insignis**, *T.* **irregularis**, *T.* **neotalpae**, *T.* **nidicolus**, *T.* **praesignis**, *T.* **similis** and *T.* **smileyi**. The majority were collected from nests of birds, mammals and insects, and from barn debris. Stored grain tarsonemids were also found in nests of birds, which suggests primary sources of stored grain infestations.

The family Tarsonoemidae includes several species which are important pests of agricultural and ornamental plants (Jeppson, Keifer & Baker, 1975), and egg parasites of pine feeding beetles (Lindquist, 1969a). Other tarsonemids are associated with honey bees (Lindquist, 1968), or with bark beetles (Lindquist, 1969b). Recently, a species of *Daidalotarsonemus* DeLeon found in human skin was believed to be the cause of the more obscure type of skin rashes similar to scabies (Hewitt & Turk, 1974; Mahunka, 1974). But the majority of the species are fungus feeders, of which certain *Tarsonemus* mites are found in stored grain and perhaps play a role in disseminating fungi that deteriorate the stored grain (Lindquist, 1972).

This paper on the taxonomic survey of the mites of New York contains descriptions and records of 21 species belonging to the family Tarsonemidae. Of these, 10 *Tarsonemus* Canestrini & Fanzago and 1 *Steneotarsonemus* Beer are new to science. One *Tarsonemus* is unnamed because of insufficient material. In addition, 5 species previously recorded from New York but not found in the present survey are listed.

The specimens were collected mostly from nests of birds, mammals and insects, and from barn debris through the use of Berlese funnels. The descriptions and records of the species are based on females only because no males or larvae were collected. The present collection from birds' nests is particularly interesting

Acknowledgments: I appreciate very much the help given to me by Dr. E. W. Baker and Mr. R. L. Smiley, both of the Systematic Entomology Laboratory, U.S. Department of Agriculture, and by Dr. E. E. Lindquist, of the Biosystematics Research Institute, Canada Agriculture. I especially thank Mr. B. M. OConnor, of the Entomology Department, Cornell University, for allowing me to study his tarsonemid collection from mammal nests, and Mr. J. R. Philips, of the Department of Forest Zoology, State University of New York at Syracuse, for the loan of his specimens collected from owl pellets.

[1] Published by Permission of the Director, New York State Science Service, Journal Series No. 221.

because it includes tarsonemids that have previously been found infesting stored grain.

Steneotarsonemus friedmani Smiley

Stenotarsonemus friedmani Smiley, 1967, Proc. Entomol. Soc. Wash. 69: 131.

Remarks. I have not collected specimens of this species. It is known only from the type-locality: van Cortlandt Park, Bronx, New York, taken from leafsheath of a grass. Three female and 1 male paratypes were kindly loaned to me by Mr. R. L. Smiley and have been examined for comparison with *S.* **oconnori**, n. sp., a related species. *S. friedmani* may be distinguished by the short dorsal body setae, by the short rodlike seta of tibiotarsus I group of sensilla, by the simple lanceolate dorsal seta on femur II, and by the slender barbed scapular setae. The spermatheca (bursa copulatrix) is small and rounded; it is large and ovoid in **oconnori**. The male is readily distinguished by the dark punctations on the venter of the propodosoma, and by the elongate striae on coxal plates III; the coxal plates IV are without such ornamentation.

Steneotarsonemus **oconnori**, n. sp.

(Figure 1)

Female. Length of idiosoma 274 μ, width 128 μ (holotype).

Dorsum. Pseudostigmatic organs elongate ovoid, attenuate at both ends, covered with spicules. Scapular setae about ⅓ longer than distance between their bases. Lateral setae of tergite I slender and longer than dorsal setae. Dorsal setae of tergite I stouter than other dorsal setae; that of tergites II–III similarly short and strong, inconspicuously barbed, almost equal in length. Lateral setae of tergite III noticeably stronger than dorsal setae. Setae of tergite IV conspicuously longer and stronger than other setae.

Venter (fig. 1). Apodemes mostly weak and indistinct. Apodemes I broadly v-shaped. Anterior median apodeme short, extending posteriorly to level of apodemes II, sometimes with weakened area between apodemes I & II, without nodule. Apodemes II straight, not clearly united with anterior median apodeme. Transverse apodeme indistinct at middle, visibly stronger laterally. Apodemes III short, with enlarged medial portion indistinct. Posterior median apodeme indistinct. Apodemes IV indistinct anteriorly, with thickened posterolateral ends extending to coxal setae IV. Coxal setae I located on apodemes I, or just posterior to apodemes I in some specimens. Coxal setae I–II short and strong, almost spinelike. Coxal setae III much longer and more slender than coxal setae IV. Metapodosomal lobe large, tongue-shaped. Spermatheca large, ovoid.

Legs. Tibiotarsus I group of sensilla consisting of 2 capitate solenidia, 1 long and 1 short, and 1 pointed seta longer than solenidia. Dorsal seta on femur I large and lanceolate, nearly smooth; that on femur II larger and lanceolate-serrate. Leg IV as long as combined length of femur-genu and tibia of leg III. Spinelike seta on tarsus II located laterad of and shorter than solendion.

Male. Unknown.

Holotype. Female, Freese Road, Tompkins County, New York, January 25, 1975, 2 ft. from nest of *Microtus pennsylvanicus* (Ord), collected by B. M. OConnor.

Paratypes. 5 females, with the same data as holotype except taken from interior, exterior and 2 inches from nest of *M. pennsylvanicus*. Holotype and 2 paratypes are deposited in the New York State Museum & Science Service at Albany; 3 paratypes are in the U.S. National Museum collection.

Remarks. The female of **oconnori**, n. sp. is very close to that of *friedmani* Smiley and *spirifex* (Marchal). *S.* **oconnori**, however, is distinguished from *friedmani* by having a long seta on the tibiotarsus I group of sensilla (this seta is very short in *friedmani*), by the large and lanceolate-serrate dorsal seta on femur II, and by the similarly strong dorsal setae of tergites I–III. In *spirifex*, the dorsal setae of tergites II–III are noticeably small, the metapodosomal lobe is large and broad and not as produced posteriorly as in **oconnori** and *friedmani*, and the scapular setae are strong, narrow saberlike and smooth. These setae are barbed and tapered to fine pointed tips in **oconnori** and *friedmani*. Also the distance between coxae IV is much wider in *spirifex* than in the other species.

This mite is named for its collector, Barry M. OConnor, of the Entomology Department, Cornell University, Ithaca, New York.

Steneotarsonemus pallidus (Banks)

Tarsonemus pallidus Banks, 1899, Proc. Entomol. Soc. Wash. 4: 295. Schaarschmidt, 1959, Beitr. Syst. u. Okol. Mitteleurop. Acarina 1(2): 761.

Steneotarsonemus pallidus, Beer, 1954, Univ. Kansas Sci. Bull. 36: 1267.

Remarks. This species is a destructive pest of strawberries, watercress, and many ornamental flowers and shrubs (Jeppson, Keifer & Baker, 1975). Female *pallidus*, except for the indistinct transverse apodeme, has strong and clearly defined ventral apodemes. It is readily distinguished from others in the genus by the following: The coxal setae I are located very much posterior to apodemes I; the apical segment of leg IV is long, about ⅔ as long as subapical segment and longer than the subapical seta; the tibiotarsus I group of sensilla consist of 2 clublike solenidia, 1 long and 1 short. I have not studied the male. It has been redescribed by Beer (1954), Schaarschmidt (1959) and Ito (1964).

Distribution. *S. pallidus* appears widely distributed throughout the world. In addition to the type material from Jamaica, New York I have examined 2 females taken from a cyclamen culture, Ithaca, October 27, 1970, by K. Kennedy.

Tarsonemus **ascitus**, n. sp.

(Figure 2)

Female. Length of idiosoma 255 μ, width 166 μ (holotype).

Dorsum. Pseudostigmatic organs elongate ovoid, covered with spicules, 2–3 larger ones distally. Propodosoma and hysterosoma uniformly and conspicuously punctate. Scapular setae shorter than distance between their insertions. Lateral and dorsal setae of tergite I slender and equal in length. Setae of tergite II and dorsal setae of tergite III similarly strong and long, inconspicuously barbed. Lateral setae of tergite III as stout as setae of tergite IV except shorter, all setae with blunt tips and inconspicuously barbed.

Venter (fig. 2). Apodemes fairly strong and well defined. Coxal plates more conspicuously punctate than dorsal surfaces. Apodemes I v-shaped. Anterior median apodeme extending posteriorly and weakly uniting with transverse apodeme, with weakened area just posterior to apodemes II, lacking nodule. Apodemes II straight, clearly not united with transverse apodeme, with posterior medial ends expanded. Transverse apodeme continuous, stronger

laterally, with slight indentation at middle. Apodemes III extending laterally beyond trochanters III, and medially to coxal setae III, lateral extensions with scalloped posterior edges as figured. Posterior median apodeme extending posteriorly to level of trochanters IV, and anteriorly to apodemes III, bifurcate anteriorly. Apodemes IV slightly crooked at middle, extending posterolaterally to coxal setae IV. Coxal setae II–IV similarly slender, about equal in length. Coxal setae I stronger than other setae, located just posterior to apodemes I. Metapodosomal lobe short and broadly rounded.

Legs. Tibiotarsus I group of sensilla consisting of 1 large clublike and 1 slender stalked capitate solenidia, and 1 stout rodlike seta. Tarsus II spinelike seta located laterodistad of solenidion, at distance about equal to length of solenidion. Femur II with small ventral ridge or flange. Leg IV as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Rt. 20 near Duanesburg, Schoharie County, August 21, 1974, taken from barn hay, by M. D. Delfinado.

Paratypes. 14 females, with the same data as holotype, some are mixed and on same slide with *T. confusus* Ewing. Holotype and 7 paratypes are deposited in the New York State Museum & Science collection at Albany; 7 paratypes are in the U.S. National Museum collection.

Remarks. The dorsal and ventral body punctations, and the characteristic lateral extensions of the apodemes III are distinctive for this new species. *T.* **ascitus**, n. sp. were found in barn debris and hay in association with *T. confusus*.

Tarsonemus confusus Ewing

(Figure 5)

Tarsonemus confusus Ewing, 1939, U.S. Dept. Agr. Tech. Bull. 653: 26. Beer, 1954, Univ. Kansas Sci. Bull. 36: 1173. Smiley, 1969, Proc. Entomol. Soc. Wash. 71: 221.

Remarks. Female *confusus* is readily distinguished by the transverse apodeme having 2 indentations close together at the middle as figured. The posterior median apodeme is sometimes weak anteriorly but clearly bifurcate. The tibiotarsus I group of sensilla consist of 2 capitate solenidia, 1 long and 1 short, and 1 fairly stout rodlike seta. The ventral metapodosomal lobe between coxae IV is small and rounded. The male femur IV is simple and lacks flange or projection; the posterior median apodeme is straight and not bifurcate, and the apodemes III–IV and the posterior median apodeme are united anteriorly. The female of *T. yoshidai* Ito, 1964, is very similar to that of *confusus*, particularly the form of the transverse apodeme. From Ito's figures, *yoshidai* differs mainly by having very long dorsal setae of tergite III in the female, and by the presence of a projection on femur IV in the male.

Distribution. Maryland (type-locality), New Jersey, New York, Virginia, North Carolina, Georgia and California. Several females from New York were taken from nests of *M. pennsylvanicus* (Ord), Ithaca, May 18, 1975, by B. M. OConnor; from bird nests, Sharon Springs, Rt. 20, October 17, 1975, Helderberg, May 6, 1973, Clifton Park, April 27, 1973 & Delmar, April 13, 1973, all by M. D. Delfinado; from barn hay & debris, Rt. 20 near Duanesburg, Schoharie County, August 21, 1974; from roadside debris, Berkshire, Rt. 90, May 16, 1975; from white pine twigs damaged by weevils, Saratoga, May 28, 1975, all by M. D. Delfinado; from milkweed culture, Rensselaerville, July 4, 1970 & from *Vespula* nest,

Ogdensburg, November 1, 1970, by G. Mullen. Additional females were taken from bird nests, Beltsville, Maryland, November 6, 1975, by E. W. Baker & M. D. Delfinado. *T. confusus* is a fairly common tarsonemid found in nests.

Tarsonemus cryptocephalus (Ewing)

(Figure 18)

Pseudotarsonemoides cryptocephalus Ewing, 1939, U.S. Dept. Agr. Tech. Bull. 653: 9.

Tarsonemus cryptocephalus, Beer, 1954, Univ. Kansas Sci. Bull. 36: 1162.

Remarks. The type specimens of *T. cryptocephalus* are in good condition. The females may be readily separated by the elongate metapodosomal lobe, by the stout dorsal setae of tergites II–IV, and by the short anterior median apodeme which is diffused and bifurcate posteriorly. In both sexes, the sensilla of tibia and tibiotarsus of leg I consist of 1 clublike solenidion and 1 rodlike seta, and tarsus II lacks the spinelike seta near the solenidion. The male posterior median apodeme is bifurcate at the posterior ½. *T. lobosus* Suski, 1962, is very likely a synonym of *T. cryptocephalus.*

Distribution. T. cryptocephalus was originally found on avocado from Chile at New York quarantine. In addition to the type material I have examined 2 females from California taken from evergreen pear. The 2 females from New York were collected from a nest in a bird house, Cambridge, April 21, 1976, by M. D. Delfinado. They were found in the nest in association with *T. granarius* Lindquist. This is a new record for the State.

Tarsonemus **dubius**, n. sp.

(Figures 3, 4)

Female. Length of idiosoma 243 μ, width 121 μ (holotype).

Dorsum (fig. 3). Pseudostigmatic organs subspherical, spiculate. Scapular setae ½ longer than distance between their bases. Lateral setae of tergite I as long as dorsal setae. Setae of tergite II stout, inconspicuously barbed, shorter than setae of tergite III. Setae of tergite III strong with lateral setae longer than dorsal setae. Setae of tergite IV 2–3 times as long as other setae, strong and conspicuously barbed.

Venter (fig. 4). Apodemes I v-shaped. Anterior median apodeme indistinct beyond posterior level of apodemes II. Apodemes II straight, weakened near and not strongly united with anterior median apodeme. Transverse apodeme indistinct at middle, strong and curved laterally. Apodemes III extending medially to coxal setae III. Posterior median apodeme short and weak, not bifurcate anteriorly. Apodemes IV weak anteriorly and not clearly united with posterior median apodeme, arcuate. Coxal setae I, II & IV similarly strong and short. Coxal setae III slender and much longer than other coxal setae. Coxal setae I located just posterior to apodemes I. Metapodosomal lobe large, broadly rounded.

Legs. Tibiotarsus I group of sensilla consisting of 1 capitate and 1 clublike solenidia, and 1 rodlike seta longer than solenidia. Genu and femur of leg II each with serrate-lanceolate seta. Spinelike seta on tarsus II located laterad of and shorter than solenidion. Leg IV as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Freese Road, Tompkins County, New York, January 25, 1975, taken 6 inches from nest of *M. pennsylvanicus* (Ord), by B. M. OConnor.

Paratypes. 6 females, with same data as holotype; 1 female, Farmingdale, Long Island, New York, June 30, 1974, from bird nest, collected by M. D. Delfinado. Holotype and 4 paratypes are deposited in the New York State Museum & Science Service collection at Albany; 3 paratypes are in the U.S. National Museum collection.

Remarks. The long setae of tergite IV will readily separate **dubius**, n. sp. from other species with short or indistinct anterior median and transverse apodemes, and from *piliger* v. Schlechtendal, a species with similarly long setae of tergite IV (see Schaarschmidt, 1959) by the structure of the apodemes.

Tarsonemus fusarii Cooreman

Tarsonemus fusarii Cooreman, 1941, Bull. Mus. r. Hist. nat. Belg. 17: 1. Schaarschmidt, 1959, Beitr. Syst. u. Okol. Mitteleurop. Acarina 1(2): 757.

Remarks. The differences between this species and *T. granarius* Lindquist are primarily as given by Lindquist (1972): Female *fusarii* has ventral apodemes on the gnathosoma; the spinelike seta near the solenidon on tarsus II is present, and it has a ventral ridge on the femur II. Not mentioned is the length of the anterior median apodeme which is noticeably longer than in *granarius*, extending posteriorly beyond apodemes II and approaching but not uniting with the transverse apodeme. I have not seen the male of *fusarii*.

Distribution. T. fusarii appears to be cosmopolitan and occurs in a wide variety of habitats, including granary samples in which *T. granarius* has been found (Lindquist, 1972). Eight females from New York were found in association with *granarius* in ant nest debris, Saratoga, September 29, 1975, by M. D. Delfinado; 1 female, Ithaca, from old lawn clippings, November 2, 1970 & 1 female, Bellport, October 30, 1970, from owl's nest, collected by M. W. Barry; 1 female, Freeville, November 19, 1970, from *Peromyscus* nest, collected by G. C. Eickwort.

Tarsonemus granarius Lindquist

Tarsonemus granarius Lindquist, 1972, Can. Entomol. 104: 1699.

Remarks. Lindquist (1972) discussed in detail the morphological and ecological similarities and differences of this species and of *T. fusarii* Cooreman. Females of *granarius* are readily distinguished from that of *fusarii* by the absence of a spinelike seta near the solenidion on tarsus II and ventral apodemes on the gnathosoma. Also in *granarius*, the anterior median apodeme is noticeably shorter than in *fusarii*, and the spermatheca (bursa copulatrix) is

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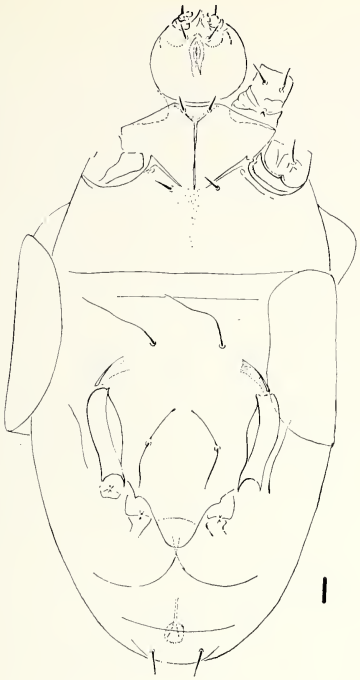
FIGS. 1–20. 1, *Steneotarsonemus* **oconnori**, n. sp., female venter; 2, *Tarsonemus* **ascitus**, n. sp., female venter; 3, *Tarsonemus* **dubius**, n. sp., female dorsum; 4, venter; 5, *Tarsonemus confusus* Ewing, female venter; 6, *Tarsonemus* **imitatus**, n. sp., female venter; 7, *Tarsonemus* **insignis**, n. sp., female venter; 8, femur I; 9, *Tarsonemus* **irregularis**, n. sp., female venter; 10, *Tarsonemus* **neotalpae**, n. sp., female venter; 11, *Tarsonemus* **nidicolus**, n. sp., female venter; 12, *Tarsonemus* **smileyi**, n. sp., female venter; 13, femur I; 14, *Tarsonemus* **praesignis**, n. sp., female venter; 15, *Tarsonemus* **similis**, n. sp., female venter; 16, *Tarsonemus talpae* Schaarschmidt, female venter; 17, *Tarsonemus waitei* Banks, female venter; 18, *Tarsonemus cryptocephalus* (Ewing), female venter; 19, *Xenotarsonemus viridis* (Ewing), female dorsum; 20, venter.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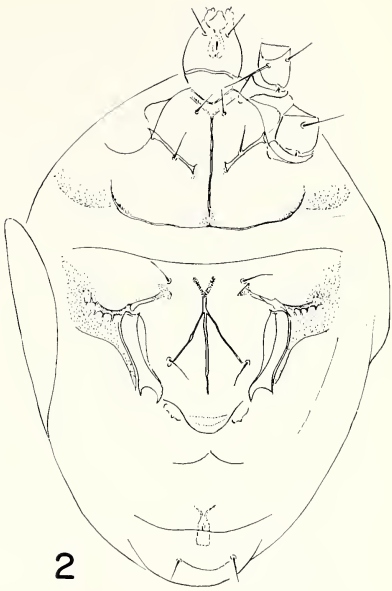
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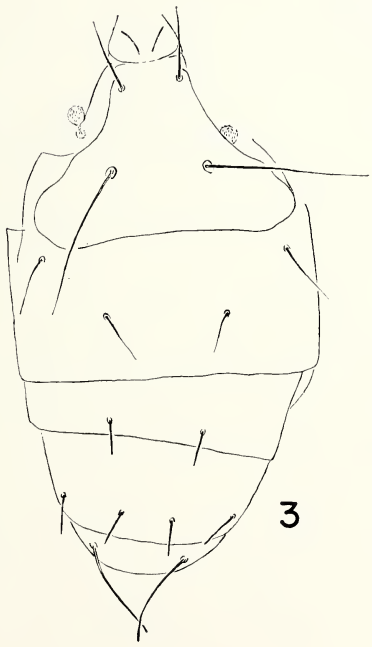
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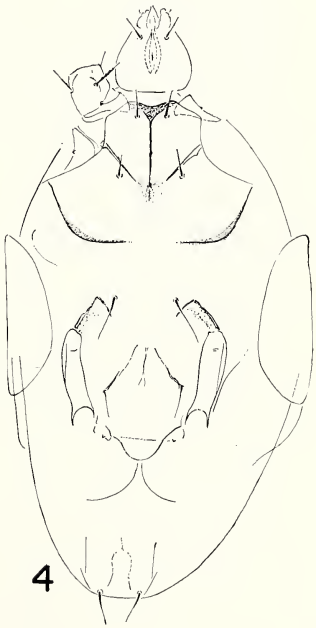
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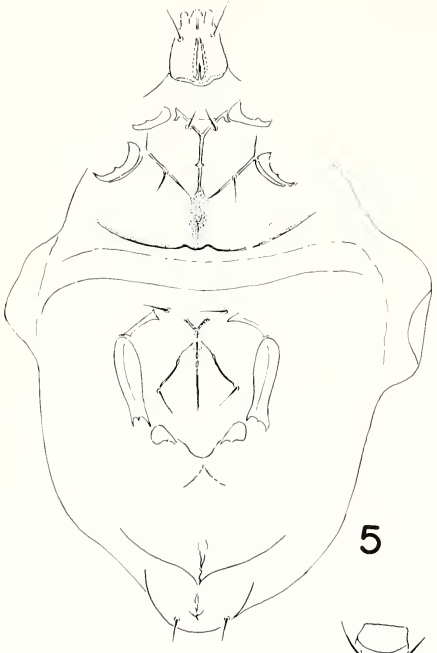
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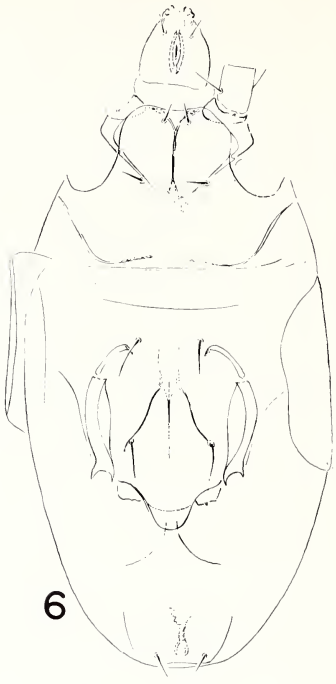
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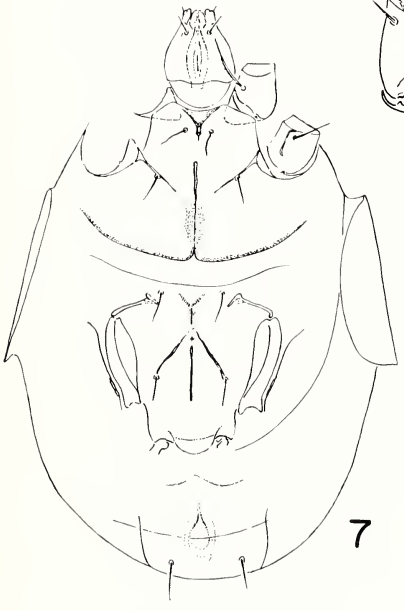
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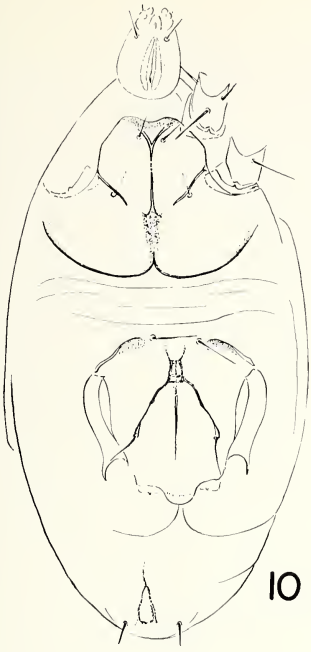

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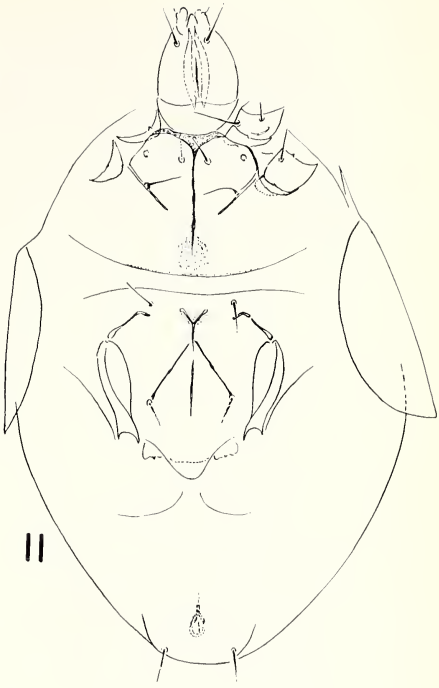

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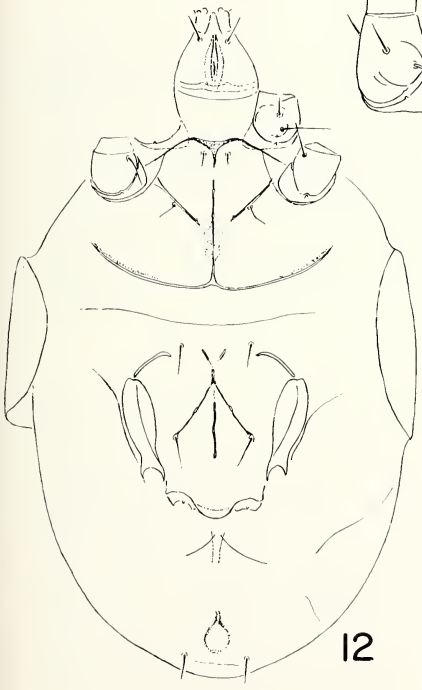

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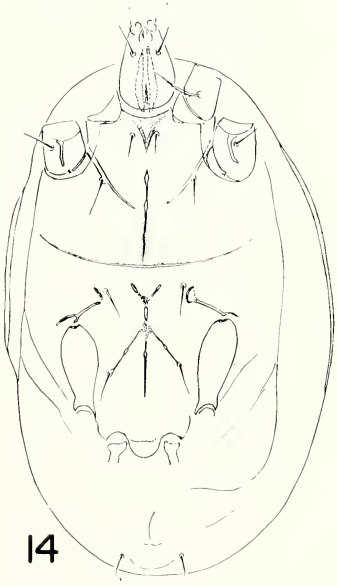

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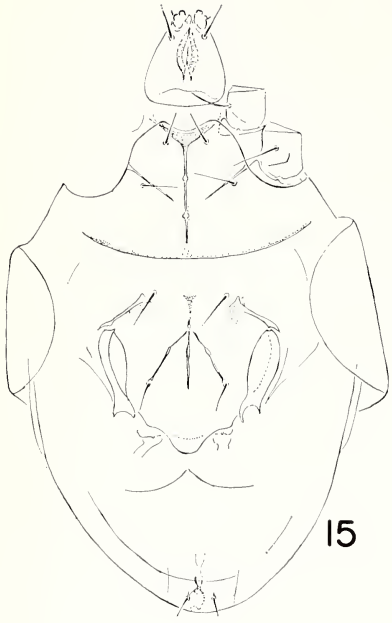
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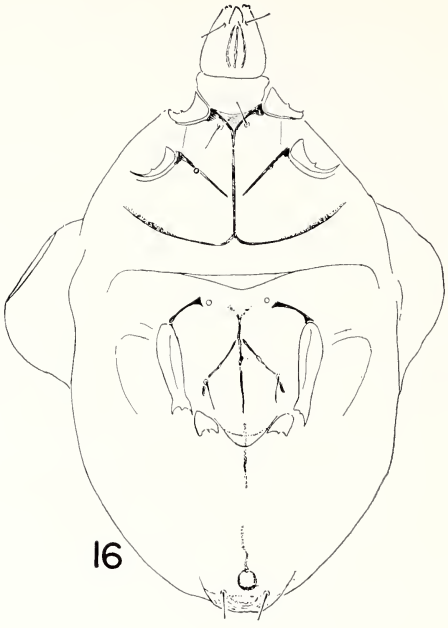
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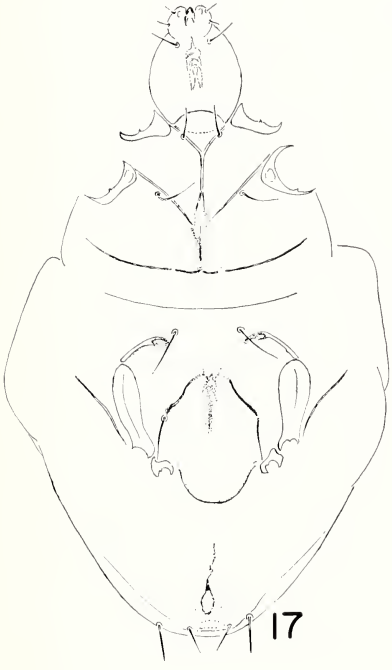
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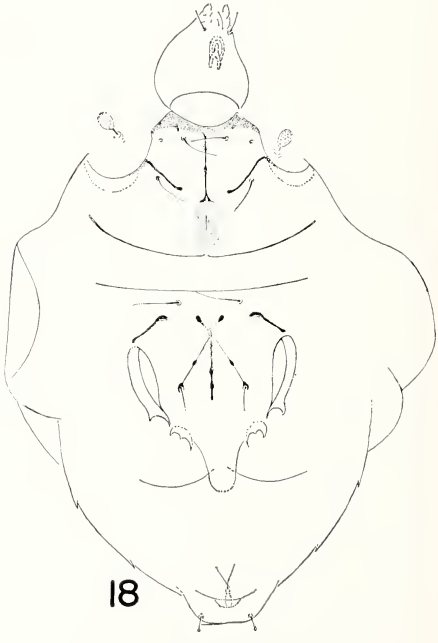
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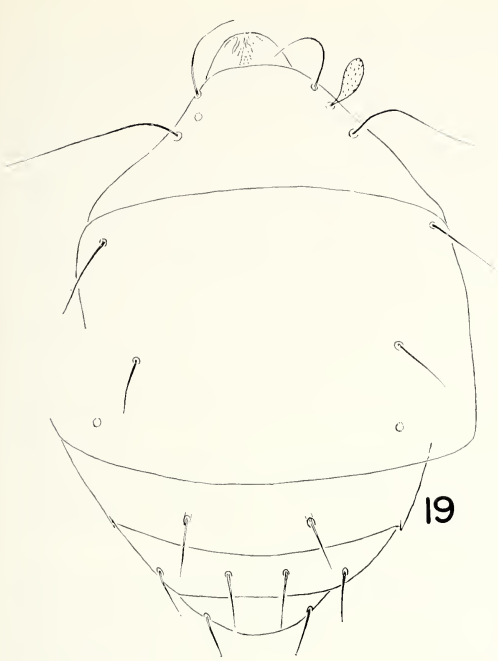

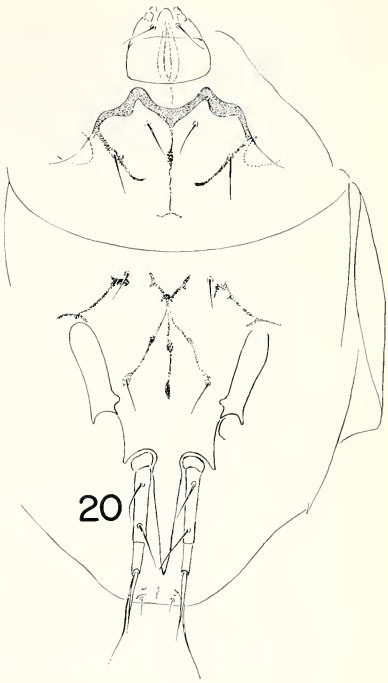

distinctive. I have not seen males of either species; there are apparently minor differences between them as described by Lindquist.

Distribution. T. granarius has been previously collected only from granaries in Canada (type-locality), Japan and Great Britain. It was collected from New York at the following localities: Saratoga, from ant nest debris, September 29, 1975 & 12 females, April 26, 1976, from bird nests; 26 females, Cambridge, April 21, 1976, from bird nests & 1 female, Sharon Springs, Rt. 20, October 17, 1975, from bird nest, all collected by M. D. Delfinado; 1 female, Dryden, October 20, 1970, from an ant hill in open field, collected by G. R. Mullen. The females from ant nest debris and bird nests were found in association with *T. fusarii.*

Tarsonemus **imitatus**, n. sp.
(Figure 6)

Female. Length of idiosoma 223 μ, width 96 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, spiculate. Scapular setae about twice as long as distance between their bases. Lateral setae of tergite I slender, longer than dorsal setae. Dorsal setae of tergites I–III stout, inconspicuously barbed, almost equal in length. Lateral setae of tergite III and setae of tergite IV barbed, longer and stouter than dorsal setae.

Venter (fig. 6). Apodemes I broadly v-shaped. Anterior median apodeme short, extending posteriorly to level of apodemes II. Apodemes II straight, not clearly united with anterior median apodeme. Transverse apodeme indistinct at middle, strong and curved laterally. Apodemes III with expanded portion extnding medially to coxal setae III. Posterior median

apodeme bifurcate anteriorly, weakened for most of its length posteriorly. Apodeme IV weak, united anteriorly with branches of posterior median apodeme, thus forming a wide M-shaped structure. Coxal setae I shorter than coxal setae II, located on or just posterior to apodemes I. Coxal setae II much stronger than coxal setae I. Coxal setae III–IV long and slender, equal in length. Metapodosomal lobe large, half-moon shaped (that of paratype slightly attenuate posteriorly).

Legs. Tibiotarsus I group of sensilla consisting of 2 solenidia, 1 long capitate and 1 short clublike, and 1 rodlike seta pointed at tip, longer than solenidia. Femur I with short, strong lanceolate-serrate seta; genu II with similar seta but longer. Spinelike seta on tarsus II located posterolaterad of and as long as solenidion. Leg IV slightly longer than combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Sharon Springs, Rt. 20, New York, October 17, 1975, taken from bird nest, by M. D. Delfinado.

Paratype. 1 female, Etna Road, Tompkins County, January 11, 1975, taken 6 inches from nest of *M. pennsylvanicus*, by B. M. OConnor (this specimen has slightly attenuate metapodosomal lobe and stronger dorsal setae of tergites I–IV). Both holotype and paratype in the New York State Museum & Science Service collection at Albany.

Remarks. This new species is very similar to **dubius**, n. sp. but differs by having shorter setae of tergite IV, by the form of apodemes IV and posterior median apodeme, and by the serrate-lanceolate seta on femur I and genu II. Both **dubius**, n. sp. and **imitatus**, n. sp. are somewhat similar to *lacustris* Schaarschmidt (1959: 764, fig. 25) by the form of the anterior median and transverse apodemes.

Tarsonemus **insignis**, n. sp.
(Figures 7, 8)

Female. Length of idiosoma 243 μ, width 147 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, spiculate. Scapular setae longer than distance between their bases. Setae of tergite I long and slender, lateral setae longer than dorsal setae. Setae of tergites II–III fairly short, about equal in length, strong and inconspicuously barbed. Setae of tergite IV longer than other setae.

Venter (fig. 7). Anterior median apodeme broadly interrupted posterior to apodemes I, extending posteriorly and uniting with transverse apodeme, with dark spot between apodemes II and transverse apodeme. Apodemes II almost straight, not united with anterior median apodeme. Transverse apodeme indented at middle where anterior median apodeme unites. Apodemes III extending medially near coxal setae III. Posterior median apodeme bifurcate anteriorly. Apodemes IV weakly united with posterior median apodeme. Coxal setae I as long as and as strong as coxal setae II–IV, located posterior to apodemes I. Metapodosomal lobe large, half-moon shaped.

Legs. Tibiotarsus I group of sensilla consisting of 1 large clublike and 1 slender capitate solenidia, and 1 stout rodlike seta. Flange on femur II large and prominent. Femur I lacking flange, ventrally with long, stout and barbed seta on ridge (fig. 8). Tarsus II spinelike seta larger than solenidion. Leg IV about as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Farmingdale, Long Island, New York, July 14, 1973, from bird nest, collected by M. D. Delfinado & M. J. Abbatiello.

Paratypes. 5 females, with same data as holotype; 4 females, same locality, June 30, 1973, from bird nests, collected by M. D. Delfinado & M. J. Abbatiello. Holotype and 5 paratypes are deposited in the New York State Museum & Science Service at Albany; 4 paratypes are in the U.S. National Museum collection.

Remarks. The females of *T.* **insignis**, n. sp. were found in bird nests in association with *T.* **smileyi**, n. sp. and *T.* **waitei** Ewing. *T.* **insignis**, *T.* **smileyi** and *T.* **praesignis**, n. spp. are characterized each in part by having interrupted anterior median apodeme between apodemes I & II and ventral flange on femur II. In **insignis** and **praesignis** the ventral seta on femur I is stout and barbed; in **smileyi** this seta is slender or normal. *T.* **insignis** may be distinguished by having similarly long and strong coxal setae I–IV, by having the spinelike seta larger than the solenidion and by the short spurlike lateral extensions of apodemes III.

Tarsonemus **irregularis**, n. sp.

(Figure 9)

Female. Length of idiosoma 230 μ, width 115 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, spiculate. Scapular setae slightly longer than distance between their bases. Lateral setae of tergite I long and slender; dorsal setae short and fairly strong. Setae of tergites II–IV similarly stout and barbed. Dorsal setae of tergite III shorter than setae of tergites II & IV.

Venter (fig. 9). Apodemes I deeply v-shaped. Anterior median apodeme indistinct or weak, uniting with transverse apodeme. Apodemes II straight, indistinctly united with anterior median apodeme. Transverse apodeme fairly strong, indented at middle where anterior median apodeme unites. Apodemes III extending medially to coxal setae III. Posterior median apodeme with very short sclerotized portion, not bifurcate anteriorly, weak or indistinct posteriorly. Apodemes IV indistinct anteriorly and not uniting with posterior median apodeme. Coxal setae I–II shorter than coxal setae III–IV. Coxal setae I located on apodemes I. Metapodosomal lobe large and broad, rounded posteriorly. Spermatheca large and ovoid.

Legs. Tibiotarsus I group of sensilla consisting of 1 short and 1 long capitate solenidia, and 1 rodlike seta. Spinelike seta on tarsus II close to and larger than solenidion. Leg IV as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Freese Road, Tompkins County, New York, January 25, 1975, taken 2 ft. from nest of *M. pennsylvanicus*, by B. M. OConnor.

Paratype. 1 female, with same data as holotype except taken in interior of nest of *M. pennsylvanicus*. Holotype and paratype are deposited in the New York State Museum & Science Service collection at Albany.

Remarks. The form of the anterior median and transverse apodemes relates **irregularis**, n. sp. to *talpae* Schaarschmidt and **neotalpae**, n. sp. *T.* **irregularis** can be separated by having a large and broad metapodosomal lobe, by apodemes IV not uniting with the posterior median apodeme, and by the large, ovoid spermatheca.

Tarsonemus **neotalpae**, n. sp.

(Figure 10)

Female. Length of idiosoma 223 μ, width 102 μ (holotype).

Dorsum. Pseudostigmatic organs spherical, spiculate. Scapular setae about equal to or slightly longer than distance between their bases. Lateral setae of tergite I much longer than dorsal setae. Setae of tergites II–III similarly short and strong. Setae of tergite IV longer than other hysterosomal setae.

Venter (fig. 10). Anterior apodemes strong and well defined, very similar in form to that of *T. talpae* Schaarschmidt. Anterior median apodeme with weakened or interrupted area posterior to apodemes I, weakened or diffused between apodemes II and transverse apodeme, posteriorly uniting with transverse apodeme. Transverse apodeme deeply indented at middle where anterior median apodeme unites. Apodemes II straight, not uniting with anterior median apodeme. Apodemes III with expanded portion extending medially near coxal setae III. Posterior median apodeme anteriorly with broad cellular neck posterior to its bifurcation and junction of apodemes IV. (In teneral specimens this area is diffused and the cavities are indistinct.) All coxal setae similarly slender. Coxal setae I located just posterior to apodemes I. Metapodosomal lobe short and broad. Spermatheca elongate and gently narrowing towards neck.

Legs. Tibiotarsus I group of sensilla consisting of 2 solenidia, 1 capitate and 1 clublike, and 1 rodlike seta. Spinelike seta on tarsus II located laterad of and as large as solenidion. Leg IV as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Cranberry Lake, St. Lawrence County, New York, August 1974, from owl pellets, collected by J. R. Philips.

Paratypes. 8 females, with same data as holotype. Holotype and 4 paratypes are deposited in the New York State Museum & Science Service at Albany; 4 paratypes in the U.S. National Museum collection.

Remarks. T. **neotalpae**, n. sp. is close to *T. talpae* Schaarschmidt in many respects but differs by having short and broad metapodosomal lobe, elongate spermatheca, and in that the posterior median apodeme has a broad cellular neck.

Tarsonemus **nidicolus**, n. sp.

(Figure 11)

Female. Length of idiosoma 225 μ, width 134 μ (holotype).

Dorsum. Pseudostigmatic organs narrow subspherical, covered with spicules. Scapular setae equal to or slightly longer than distance between their bases. Setae of tergite I slender and much longer than other setae. All setae of tergites II–IV strong and stout, with blunt tips and tiny barbs.

Venter (fig. 11). Apodemes strong and well defined. Apodemes I nearly straight and T-shaped with anterior median apodeme. Anterior median apodeme posteriorly extending beyond apodemes II, approaching but not uniting with transverse apodeme, dark or cloudy at this area, with 2 nodules and sometimes with weakened area between apodemes I & II. Apodemes II almost straight, not uniting with anterior median apodeme. Transverse apodeme continuous, arcuate. Apodemes III extending medially just posterior to coxal setae III. Posterior median

apodeme with bifurcate end extending anteriorly to level of apodemes III. Apodemes IV almost straight, uniting anteriorly with posterior median apodeme. All coxal setae fairly weak and slender. Coxal setae I located just posterior to apodemes I. Metapodosomal lobe small, slightly attenuate posteriorly.

Legs. Tibiotarsus I group of sensilla consisting of 1 capitate and 1 clublike solenidia, and 1 rodlike seta. Femur of legs I & II each with large ventral flange which may be seen as strong ridge or small protuberance in some specimens if legs not properly oriented. Spinelike seta on tarsus II close to and about as large as solenidion. Leg IV slightly longer than combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Sharon Springs, Rt. 20, New York, taken from bird nest, by M. D. Delfinado.

Paratypes. 39 females, with same data as holotype; 4 females, Beltsville, Maryland, November 6, 1875, from bird nests, collected by E. W. Baker & M. D. Delfinado; 1 female, Ithaca, New York, May 18, 1974, from interior of nest of *M. pennsylvanicus*, collected by B. M. OConnor; 1 female, Ogdensburg, New York, November 1, 1970, from *Vespula* nest, collected by G. R. Mullen. Holotype and 25 paratypes are deposited in th New York State Museum & Science Service at Albany; 20 paratypes are in the U.S. National Museum collection.

Remarks. The presence of the ventral flange on both femora I & II, the continuous anterior median apodeme which extends to near the transverse apodeme, and the similarly strong and stout setae of tergites II–IV are distinctive for **nidicolus** n. sp.

Tarsonemus **praesignis**, n. sp.

(Figure 14)

Female. Length of idiosoma 166 μ, width 96 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, spiculate. Scapular setae slightly shorter than distance between their bases. Setae of tergite I long and slender, equal in length. Setae of tergite II and dorsal setae of tergite III shorter than lateral setae of tergite III and setae of tergite IV, all setae fairly strong, with blunt tips and inconspicuously barbed.

Venter (fig. 14). Apodemes well defined. Apodemes I v-shaped. Anterior median apodeme broadly interrupted posterior to apodemes I, posteriorly extending to and weakly uniting with transverse apodeme. Transverse apodeme continuous and arcuate. Apodemes II slightly curved, clearly not uniting with anterior median apodeme. Apodemes III with short spurlike lateral extensions (not seen in paratype specimen after remounting). Posterior median apodeme bifurcate anteriorly, extending to level of coxal setae III. Apodemes IV straight, anteriorly uniting with posterior median apodeme. All coxal setae similarly slender. Coxal setae I slightly shorter than other setae, located posterior to apodemes I. Metapodosomal lobe small, rounded posteriorly. Spermatheca small, bulbous.

Legs. Tibiotarsus I group of sensilla consisting of 1 small clublike and 1 long capitate solenidia, and 1 rodlike seta. Femur II with prominent ventral flange. Femur I lacking flange, with strong barbed seta on ridge similar to that of *T.* **insignis**, n. sp. Spinelike seta on tarsus II large and twice as long as solenidion. Leg IV about as long as combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Saratoga, New York, July 26, 1973, taken from flycatcher nest, by M. D. Delfinado.

Paratype. 1 female, with same data as holotype. Holotype and paratype are deposited in the New York State Museum & Science Service at Albany.

Remarks. This new species is closely related to **insignis**, n. sp. *T.* **praesignis** may be distinguished by the large spinelike seta near the solenidion on tarsus II, by the apodemes III with short spurlike lateral extensions, and by the transverse apodeme being arcuate and not indented at the middle.

Tarsonemus **smileyi**, n. sp.

(Figures 12, 13)

Female. Length of idiosoma 217 μ, width 128 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, spiculate, with 1–2 larger spicules distally. Scapular setae slightly longer than distance between their bases. Lateral and dorsal setae of tergite I fairly short and slender. Setae of tergites II–IV similarly short and strong, with blunt tips, inconspicuously barbed.

Venter (fig. 12). Apodemes fairly well defined. Apodemes I v-shaped. Anterior median apodeme broadly interrupted between apodemes I & II, posteriorly extending and uniting with transverse apodeme, area between apodemes II and transverse apodeme diffused or weakened. Apodemes II approaching anterior median apodeme but not uniting with it, inner ends curved. Transverse apodeme arcuate and indented at middle where anterior median apodeme unites. Apodemes III extending medially to coxal setae III. Posterior median apodeme indistinct or weakened at midlength where apodemes IV unite, bifurcate anteriorly. Apodemes IV rather weak, uniting anteriorly with posterior median apodeme, crooked at middle, extending posterolaterally to coxal setae IV. Coxal setae I shorter than coxal setae II–IV. Metapodosomal lobe short and broad, rounded posteriorly. Spermatheca large and globular.

Legs. Tibiotarsus I group of sensilla consisting of 1 large clublike and 1 slender stalked capitate solenidia, and 1 rodlike seta. Spinelike seta on tarsus II near and as large as solenidion. Femur II with small rounded flange, appearing as ridge in some specimens. Femur I ventrally with long and slender inconspicuously barbed seta on ridge (fig. 14).

Male. Unknown.

Holotype. Female, Farmingdale, Long Island, New York, June 30, 1973, taken from bird nest, by M. D. Delfinado & M. J. Abbatiello.

Paratypes. 9 females, with same data as holotype; 2 females, Rt. 20, near Duanesburg, Schoharie County, August 21, 1974, from hay, collected by M. D. Delfinado. Holotype and 5 paratypes are deposited in the New York State Museum & Science Service collection at Albany; 4 paratypes in the U.S. National Museum collection.

Remarks. *T.* **smileyi**, n. sp. is distinguished by having the ventral seta on femur I slender and not as strong as in the related species, from *T.* **insignis**, n. sp. and *T.* **praesignis**, n. sp. by the short coxal setae I, and by similarly short and strong setae of tergites II–IV. Also the flange on femur II is small and not as developed as in the other species.

This mite is named for Mr. R. L. Smiley, of the Systematic Entomology Laboratory, U.S. Department of Agriculture, Beltsville, Maryland.

Tarsonemus **similis**, n. sp.

(Figure 15)

Female. Length of idiosoma 223 μ, width 121 μ (holotype).

Dorsum. Pseudostigmatic organs subspherical, covered with spicules. Scapular setae slightly longer than distance between their bases. All setae of tergites I–IV similarly short and slender.

Venter (fig. 15). Apodemes strong and well defined. Apodemes I arcuate. Anterior median apodeme posteriorly approaching transverse apodeme and not uniting with it, with 2 nodules and 2 weakened spots between apodemes I & II. Apodemes II straight, with inner ends curved, not uniting with anterior median apodeme. Transverse apodeme continuous and slightly curved at middle (may not be noticeable in some specimens). Apodemes III with enlarged portion extending medially to coxal setae III. Posterior median apodeme extending anteriorly to level of apodemes III, with thickened expanded tip but not clearly bifurcate. Apodemes IV slightly curved, uniting anteriorly with posterior median apodeme, extending posterolaterally to coxal setae IV. All coxal setae similarly long and slender. Coxal setae I located just posterior to apodemes I. Metapodosomal lobe fairly small, slightly attenuate posteriorly. Spermatheca small and rounded.

Legs. Tibiotarsus I group of sensilla consisting of 2 solenidia of equal length, 1 clublike and 1 capitate, and 1 rodlike seta longer than solenidia. Ventral flange on femur II small and rounded; that on femur I much smaller, appearing as ridge in some specimens. Spinelike seta on tarsus II close to and smaller than solenidion. Leg IV slightly longer than combined length of femur-genu and tibia of leg III.

Male. Unknown.

Holotype. Female, Delmar, New York, April 13, 1973, taken from bird nest, by M. D. Delfinado.

Paratypes. 12 females, Helderberg, New York, May 6, 1973; 2 females, Clifton Park, April 27, 1973, all collected from bird nests, by M. D. Delfinado; 2 females, Ithaca, Savage Farm, New York, March 20, 1974, taken from exterior portion of nest of *M. pennsylvanicus*, by B. M. OConnor. Holotype and 8 paratypes are deposited in the New York State Museum & Science Service at Albany; 6 paratypes are in the U.S. National Museum collection.

Remarks. The females of **similis**, n. sp. are similar to those of *T.* **nidicolus**, n. sp. *T.* **similis** can be distinguished as follows: all the setae of tergites I–IV are similarly short and slender; both solenidia of tibiotarsus I group of sensilla are of equal length, and the posterior median apodeme is not bifurcate anteriorly.

Tarsonemus talpae Schaarschmidt

(Figure 16)

Tarsonemus talpae Schaarschmidt, 1959, Beit. Syst. u. Okol. Mitteleurop. Acarina 1(2): 764.

Remarks. This species has distinctive and well-defined anterior median and transverse apodemes, the former may be weakened or interrupted for a short distance between apodemes I & II. The apodemes II are strong and straight, approaching the anterior median apodeme but not uniting with it. The posterior median apodeme is normal, bifurcate anteriorly. The ventral metapodosomal lobe is small and attenuate posteriorly. The spermatheca is fairly large and rounded. The male is not known.

Distribution. Europe (exact type-locality not mentioned). Specimens from New York were collected as follows: 2 females, Freese Road, Tompkins County, January 25, 1975, taken 2 inches from and exterior of nest of *M. pennsylvanicus* & 1 female, Spencer Lake, Tioga County, from nest of shrew on stream bank, November 14, 1974, collected by B. M. OConnor; 8 females, Farmingdale, Long Island, from bird nests, June 30, 1973; 2 females, Rt. 20, near Duanesburg, August 21, 1975, from barn hay & 1 female, Delmar, September 3, 1975, from house dust, all collected by M. D. Delfinado. These are also new records for North America.

Tarsonemus waitei Banks

(Figure 17)

Tarsonemus waitei Banks, 1904, Proc. Entomol. Soc. Wash. 14: 96. Beer, 1954, Univ. Kansas Sci. Bull. 36: 1181.

Remarks. Dr. E. E. Lindquist, of the Biosystematics Research Institute, Canada Agriculture, kindly informed me that the specimens which I have determined as *T. setifer* Ewing are *waitei* Banks. Subsequent examination of the type females of both *waitei* and *setifer* suggests that these 2 species are conspecific. I find no significant characters to separate the 2 females. But I cannot be certain because the type males of *waitei* are badly shriveled and unrecognizable for comparison with those of *setifer.* Female *waitei* may be characterized as follows: The transverse apodeme has 2 short weakened areas at the middle which may appear interrupted in some specimens (in the type specimen the transverse apodeme appears weak at the middle). The anterior median apodeme is bifurcate and diffused before or at the posterior level of apodemes II. The apodemes II are strong and straight, ending at the diffused area of the anterior median apodeme. The posterior median apodeme is weak and does not extend anteriorly. The ventral metapodosomal lobe is conspicuously large and broad, rounded posteriorly. The setae of tergites II–IV are strong and barbed, with the dorsal setae of tergite III being longer and stronger than other setae. Sensilla of the tibiotarsus I consist of 1 clublike solenidion and rodlike seta. Tarsus II lacks the spinelike seta near the solenidion. The redescription and figures of *waitei* by Beer (1954) is apparently of a different species. I have not studied the male.

Distribution. T. waitei has been previously recorded from New York. It was recently found in large numbers in nests of birds from the following localities: Sharon Springs, Rt. 20, October 17, 1975; Helderberg, May 18, 1973; Clifton Park, April 27, 1973; Delmar, April 13, 1973 & Farmingdale, Long Island, June 30, 1973; and from *Peromyscus* nest, Niskayuna, April 27, 1973, and from white pine cones, Saratoga, May 22, 1973, all were collected by M. D. Delfinado.

Tarsonemus unnamed sp.

One female collected from a wood duck nest (Saratoga, New York, October 29, 1975, by M. D. Delfinado) resembles *T. crassus* Schaarschmidt, and belongs to the species group having the apodemes III extending laterally beyond trochanters III. It has the following characteristics: The pseudostigmatic organ (1 missing) is large and ovoid, spiculate. The scapular setae are short and weak, about ½ the distance between their bases. The lateral setae of tergite I are seemingly smaller and weaker than the dorsal setae. The anterior median apodeme extends posteriorly beyond apodemes II but does not unite with the transverse apodeme. Apodemes III have long and slender lateral extensions. The apodemes IV are united at midlength of the posterior median apodeme. All coxal setae are weak. Femur II has a prominent ventral flange. The sensilla of tibiotarsus I consist of 1 clublike and 1 slender capitate solenidia, and 1 rodlike seta. The spinelike seta on tarsus II is small

and located very much distad of the solenidion. Leg IV (1 missing) is shorter than combined length of femur-genu and tibia of leg III.

Xenotarsonemus viridis (Ewing)

(Figures 19, 20)

Tarsonemus viridis Ewing, 1939, U.S. Dept. Agr. Tech. Bull. 653: 35.

Xenotarsonemus viridis, Beer, 1954, Univ. Kansas Sci. Bull. 36: 1314.

Remarks. The female *viridis* which is labelled type in the U.S. National Museum collection at Beltsville, Maryland is in very poor condition: only the legs III & IV and the ventral metapodosomal lobe are intact and recognizable. Mr. Smiley, however, kindly loaned me a female specimen which undoubtedly is one of the several specimens on which Ewing based his original description. It has been remounted and is in good condition. The 2 females from New York fit *viridis*. The long, pointed daggershaped metapodosomal lobe which extends to the posterior level of legs IV, and the large and well developed flange on femur II are distinctive characteristics of the female. I have not studied the male; it was redescribed and figured by Beer (1954).

Distribution. Maryland (type-locality). Two females were collected near and from the exterior portion of a nest of *M. pennsylvanicus*, Freese Road, Tompkins County, January 25, 1975 & Ithaca, Savage Farm, New York, March 20, 1974, by B. M. OConnor. This is a new record for the State.

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BOOK REVIEW

Butterflies of West Malaysia and Singapore. W. A. Fleming. 1975. Longman Malaysia Sdn. Berhad, Kuala Lumpur. Vol. 1, x + 64 pp., 54 color plates. Vol. 2, x + 93 pp., 90 color plates. £19.50.

The area specifically covered is roughly the broader distal portion of the Malay Peninsula that extends from mainland Asia toward the Indonesian islands. This is an especially interesting area, not only because of the wealth and intrinsic interest of its species, but because of the vastly complex zoogeography of the whole Indo-Australian Region. A total of 1000 species and 95 additional subspecies are covered, including the Hesperiidae, under the general term 'butterfly'. All species recorded from the area are included. For each are given the general range of the species and more specific records in the area, as well as short notes on identification, habitat and foodplants (when known). Nearly all are illustrated by color photographs, both sexes and the underside being shown in many instances. Considerable preliminary information is given about butterfly characteristics in general and the complex geography of the region.

We are glad to note a plea for the conservation of rare species, some of which are definitely endangered. This is all the more pertinent because of commercial interests in India, Taiwan and the Philippines, and unscrupulous collectors elsewhere, who are flooding the markets with literally hundreds of thousands of specimens.

The author has lived in the region since 1937, and so has wide field experience with the majority of the species. The 1579 illustrations, which show excellent color reproduction, are mostly from his own collection but partly from other collections including the British Museum (Natural History). The nomenclature appears to be up to standard, in general following that of Corbet and Pendlebury's *The Butterflies of the Malay Peninsula* (1956), now out of print. This should be an interesting and worthwhile book for everyone interested in butterflies on a worldwide bases, as well as for specialists in the region.

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Mortality Factors Affecting *Eurosta solidaginis* (Diptera: Tephritidae)[1]

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Abstract: The degree of parasitism of *Eurosta solidaginis* (Fitch) by *Eurytoma gigantea* Walsh and *E. obtusiventris* Gahan and of predation upon these species by birds was verified. Gall height positively influenced bird predation and parasitism by *Eurytoma obtusiventris*, whereas gall diameter was significantly related to bird predation and parasitism by *Eurytoma gigantea*. Multiple galls were favored by birds. The late summer emergence of *E. gigantea* was substantiated.

INTRODUCTION

The goldenrod ball gall fly, *Eurosta solidaginis* (Fitch), its parasites *Eurytoma gigantea* Walsh and *E. obtusiventris* Gahan (Hymenoptera: Eurytomidae), the so-called "accidental" predator *Mordellestina unicolor* Lec. (Coleoptera: Mordellidae), and the predation upon these species by birds have been studied for over a century. Life history and distributional data are plentiful (see Hughes, 1934; Uhler, 1951, 1961; Miller, 1959), but information on gall height and diameter in relation to parasitism or predation and data on larval and pupal biomass is lacking. This paper reports on unknown aspects of the biology of *Eurosta solidaginis* and its parasites and predators, with emphasis on mortality factors in relation to multiple galls, gall diameter, and gall height.

METHODS AND MATERIALS

In February 1975, 581 *Eurosta solidaginis* galls were collected from the stems of *Solidago canadensis* var. *scabra* (Muhl) T. & G.[2] in an abandoned field on the outskirts of Syracuse, N.Y. Two separate collections of the galls were made in a 3600 sq m area, utilizing a square meter grid random sampling method. Within this area, the gall density was 3.4 galls per sq m. The galls were placed in a

Acknowledgments: We are grateful to Richard Lewis for assistance in statistical analyses and computer programming, and to George Snyder for preparation of the photographs and graphical data.

[1] Submitted in partial fulfillment of the requirements of Forest Biology 498.

[2] Specimens have been deposited in the S.U.N.Y. College of Environmental Science and Forestry Herbarium.

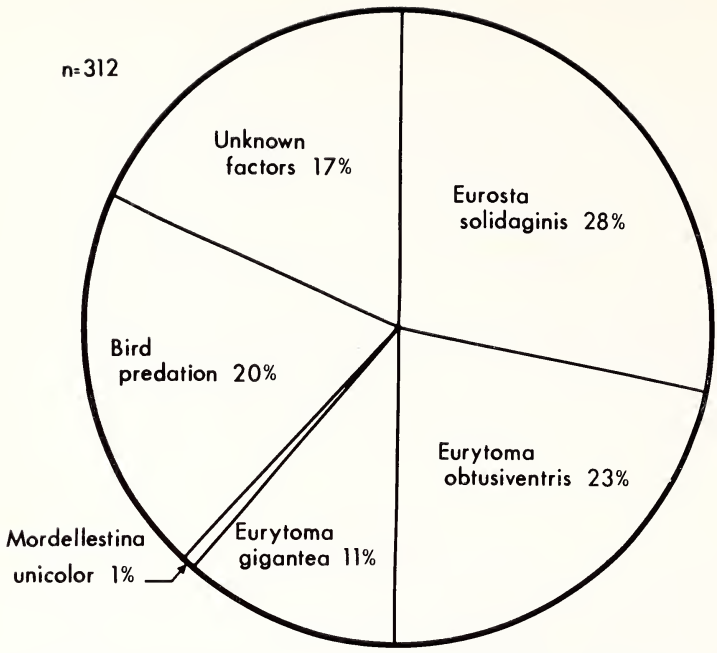

FIG. 1. Mortality factors (in pct) for a population of *Eurosta solidaginis* from Syracuse, N.Y. (Determined from overwintering galls).

Sherer environmental control chamber and subjected to a series of gradual temperature increases designed to parallel field temperatures for that time of year. Humidity was maintained at 76 ± 2° by placing the galls inside airtight 1-gal. glass jars, each containing a 1 oz cup of saturated NaCl solution. Galls from one collection were later transferred to 4 oz plastic containers for emergence studies. Galls from the other collection were dissected during February and March for larval and pupal biomass studies. In the latter studies the larvae were removed from the galls, placed in a container under optimal humidity conditions, and periodically observed, measured, and weighed. Overwintering host and parasite larvae that were removed from their galls and subjected to suitable humidity and temperature treatments developed concurrently with undisturbed galls. The exposed insects yielded living adults a day in advance of the undisturbed galls.

In all cases, gall height was measured along the stem from the ground surface to the gall base. Gall diameter was taken as the widest axis of the gall perpendicular to the stem. Statistical significance of the results was determined through combined application of Student's t, F distribution, Chi-square and classed Chi-square statistical analyses (see Snedecor, 1956). Null hypothesis rejection was set at the 95% level of confidence.

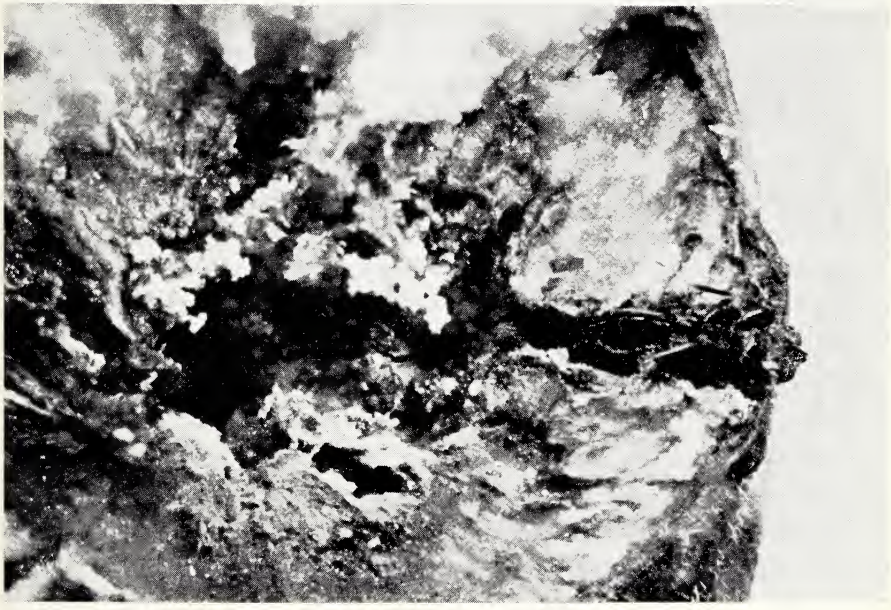

Fig. 2. Gall of *Eurosta solidaginis* showing characteristic downy woodpecker predation.

Fig. 3. Adult *Eurytoma gigantea* emerging in the field from late summer gall.

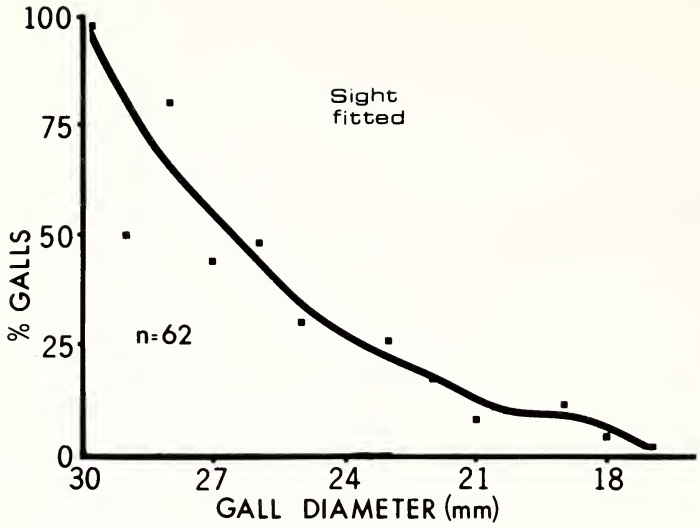

FIG. 4. Percent galls attacked by birds plotted against gall diameter in mm.

RESULTS

Parasitism of *Eurosta solidaginis* by *Eurytoma gigantea* and *E. obtusiventris* was confirmed (fig. 1). Double parasitism, involving the gall cavity being occupied by single individuals each of *Eurytoma gigantea* and *E. obtusiventris*, was rare—2 of 538 galls or 0.4%. In such cases, adults of both species developed and emerged normally. Only 0.6% of the galls that were opened contained larvae or adults of the mordellid *Mordellestina unicolor* Leconte. In one gall cavity, the beetle larva had consumed a larva of the parasite *Eurytoma obtusiventris*, as evidenced by its empty pupal case, while another gall produced living adults of both *M. unicolor* and *Eurosta solidaginis*.

We verified Milne's (1940) suspicions that the Downy Woodpecker, *Dendrocopus pubescens* (Swainson), is a major predator by observing individuals of this species attacking galls in late October 1974 and 1975. The act of locating and opening the gall and feeding upon the larva of *Eurosta solidaginis* often took less than 30 sec, resulting in a roughly conical depression leading into the central cavity of the gall (fig. 2). If the gall cavity contained a larva of *Eurytoma obtusiventris*, however, it was often not consumed.

The numbers of *Eurosta solidaginis* that emerged and were sexed comprised roughly equal numbers of males and females. Both pupation and emergence of the host species preceded that of either *Eurytoma* species. Adults of *E. gigantea* were the last of the three species to emerge under laboratory conditions.

All individuals of *E. obtusiventris* that were reared and collected in connection

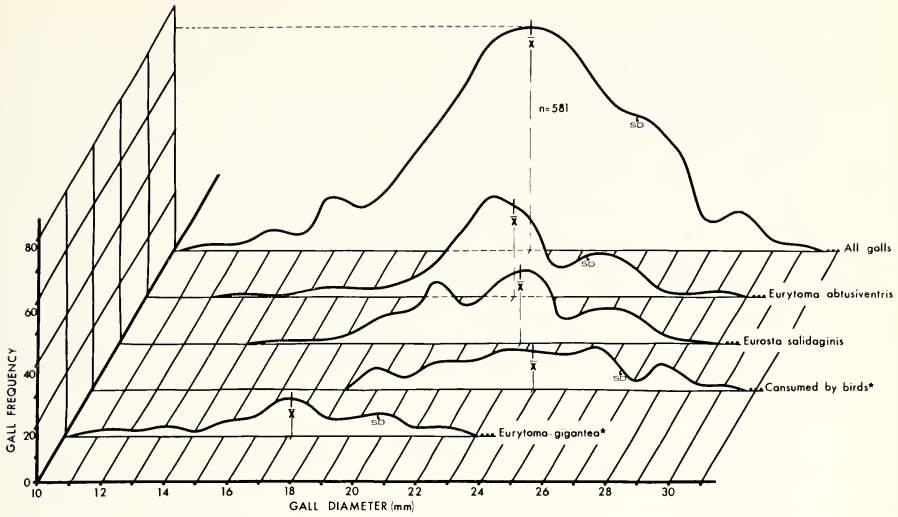

Fig. 5. Frequency curves for gall diameter in mm. Mean ($\bar{x}$) and standard deviation (SD) are shown for each curve. * indicates statistical significance at the 5% level.

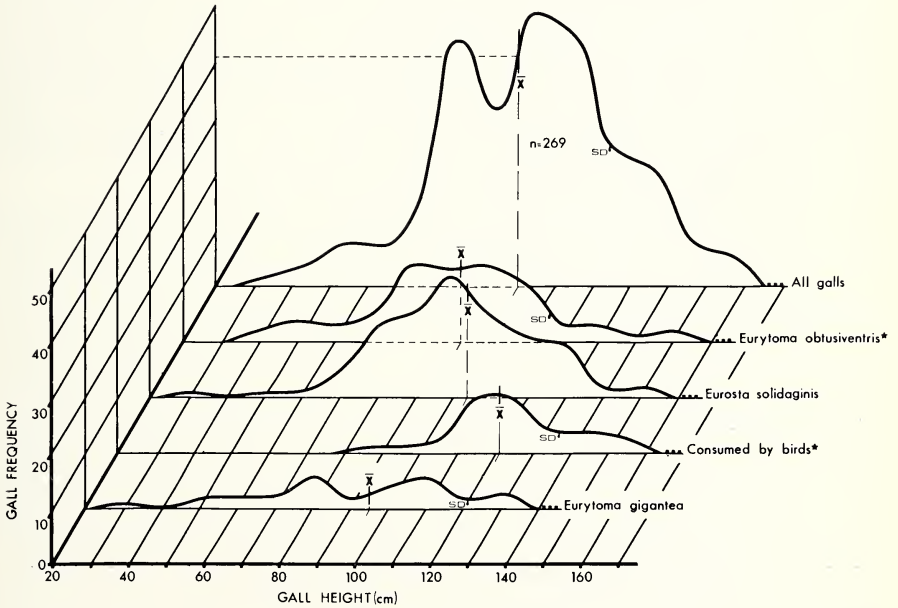

Fig. 6. Frequency curves for gall height in cm. Mean ($\bar{x}$) and standard deviation (SD) are shown for each curve. * indicates statistical significance at the 5% level.

with our study were females. The larvae of these parasites overwintered inside the smaller premature host pupae.

Approximately half of the galls which contained *E. gigantea* were involved in late summer emergence in 1975 (fig. 3).

Multiple galls[3] were fed upon more by birds than were single galls. The incidence of either parasite species was, in contrast, not related to multiple versus single galls.

Gall diameter was related to both predation by birds and parasitism by *Eurytoma gigantea* (fig. 4, 5). Galls higher on the stems were fed upon proportionately more by birds, whereas galls lower on the stems were parasitized more significantly by *E. obtusiventris* (fig. 6). Galls whose cavities were occupied by *E. gigantea* were also located lower on the stems but borderline t and F values coupled with large SE_M were inconclusive.

No significant correlations between larval masses of *Eurosta solidaginis*, *Eurytoma gigantea* or *E. obtusiventris* and gall diameter or height were found.

DISCUSSION

The rather similar percentages of parasitism reported by Hughes (1934), Uhler (1951) and Miller (1959) and observed by us for *Eurytoma gigantea* and *E. obtusiventris* on *Eurosta solidaginis* emphasize the fact that these three species have attained a dynamic equilibrium in their relationships. The rare instances of double parasitism indicate that, at times, both *Eurytoma gigantea* and *E. obtusiventris* can coexist within the same gall cavity. The very low percentage of the commensal but occasional predator, *Mordellestina unicolor*, that we encountered in our study may be incidental to the ecology of the study area. Both Hughes (1934) and Uhler (1951) reported a much higher incidence of *M. unicolor* within the gall cavity of *Eurosta solidaginis*.

The relatively high amount (20%) of bird predation which we found had been surpassed only by the rather high (44.8%) mortality reported by Milne (1940). Uhler (1951, 1961) and Miller (1959) noted much lower instances of bird predation. The relatively high degree of mortality via bird predation that we observed may be related to the proximity of a wooded cemetery and hedgerow surrounding the study area, both of which supported large bird populations.

The fact that the larva of *Eurytoma obtusiventris* was often not consumed whereas those of *E. gigantea* and *Eurosta solidaginis* were invariably eaten by birds is puzzling. The position of the parasitic *Eurytoma obtusiventris* inside the puparium of its host may provide a negative stimulus to the bird predator, whereas that of the host larva may be attractive. Furthermore, the "varnish-like" coating on the walls of the gall cavity, which is associated only with *Eurytoma*

[3] More than one *Eurosta solidaginis* gall on a single goldenrod stem.

obtusiventris, may be distasteful or act as a repellent to the bird predator, as suggested by Milne (1940).

The results of our emergence studies concur with those of Hughes (1934), Uhler (1951), and Miller (1959), i.e., adults of *Eurosta solidaginis* emerge first followed by those of *Eurytoma obtusiventris* and later, *E. gigantea*. Although Uhler (1951, 1961) contended that *E. gigantea* has only a single emergence period per year, our studies confirm those of Miller (1959) and indicate that there are two emergence periods annually; one in late summer, the other in late spring. We found that approximately equal numbers of adults were involved in the two emergences, whereas Miller (1959) reported that three-fourths of his Ohio population of *E. gigantea* emerged during the spring. The advantages and disadvantages of the "early" and "late" emergences of this parasite have not been ascertained.

Multiple galls were fed upon significantly more by birds than were single galls. It would be advantageous for birds to concentrate their feeding on multiple galls because they could consume more larval *Eurosta solidaginis* with less searching. Thus, multiple galls may be visually more attractive to birds than single galls. Similarly, galls of greater diameters and those higher on the stem were fed upon more by birds because they are more easily recognized visually and are more easily accessible.

Galls occupied by *Eurytoma gigantea* were rarely the object of bird predation due, we believe, to their reduced gall diameters. Such undersized galls were first noted by Johannsen (1910). Since the larva of *Eurosta solidaginis* apparently produces the gall-forming hormone(s) and the rather rapid attack on this host by the external parasite *Eurytoma gigantea* occurs when gall growth is only 65% completed (Uhler, 1951), *E. gigantea* must interfere with the host larva's ability to produce gall-forming hormone(s) resulting in an undersized gall. The slower, internal type of parasitism of *Eurytoma obtusiventris* does not influence gall formation at an early stage, resulting in a full-sized, completed gall.

Galls lower on the stems were attacked less often by birds but were parasitized more frequently by *Eurytoma obtusiventris*. In the former case we believe that a negative visual stimulus is involved. *E. obtusiventris* may be associated with galls lower on the stems because of its small size, its weak flight capacity and its inability to cope with strong wind. Uhler, on the other hand, has indicated (pers. comm.) that because both oviposition by *Eurosta solidaginis* and subsequent parasitism by *Eurytoma obtusiventris* takes place early in the season none of these factors would be important.

Gall diameter or height and larval mass show no significant correlations, suggesting that bird predation does not exert a significant pressure on the mass of *Eurosta solidaginis* or its parasites. Thus, inherent plant factors such as tissue and sap production may be ultimately responsible for the final larval mass.

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BOOK REVIEW

Mosquito ecology: Field sampling methods. M. W. Service. 583 pp. Hallstead Press—John Wiley & Sons, New York-Toronto. $75.00. 1976.

Mosquitoes are among the most important vectors of disease agents. Therefore information on mosquito ecology is of considerable public health importance. The author of this impressive volume assembled in eleven chapters detailed information on various species of adult mosquitoes as well as of their eggs and larvae. The chapters dealing with the marking, release, and recapture of mosquitoes, as well as the estimation of total insect populations, described in detail, as well as the dispersal, longevity, and calculation of reproductive potential will be among the topics of special interest to those studying mosquito population dynamics. Numerous diagrams and illustrations of trays, traps, and aspirators have been included. Sampling the egg, larval, and adult population, the trapping of adults with non-attractants, with animal-baited, carbon dioxide, and sound traps, sampling of adult population, experimental hut techniques for evaluation of insecticides, recapture techniques, estimation of mortalities, and indices of association between species and species diversity are masterfully presented. The book is aimed at field workers as well as at population researchers and ecologists. Its clarity and good quality of illustrations will be welcomed by all readers. The indexing is adequate.

The book is highly recommended for teachers, students, and for college and experimental station libraries, as well as for individuals—if they can afford it.

KARL MARAMOROSCH
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Non-Functional Ovaries in *Bathyplectes* spp. (Hymenoptera: Ichneumonidae), Larval Parasitoids of the Alfalfa Weevil (Coleoptera: Curculionidae)

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Abstract: 9–14% of all female *Bathyplectes anurus, curculionis* and *stenostigma* dissected had non-functional ovaries, rendering them sterile. The presence of these individuals in a population has a detrimental impact on the parasitoid's ability to control their host, the alfalfa weevil.

INTRODUCTION

Recently increasing emphasis has been placed on evaluating factors influencing the impact of parasitoids, especially *Bathyplectes curculionis*, on alfalfa weevil population density. The impact of host encapsulation of parasitoid eggs (Puttler 1974, Berberet and Gibson 1976), hyperparasitism (Caldwell and Wilson 1975, Best and Simpson 1975), parasitoid cocoon predation (Cherry and Armbrust 1975) and winter kill of parasitoid cocoons (Armbrust et al. 1972) has been studied and found to lower the number of available female *B. curculionis* in succeeding generations. Here I describe the presence and impact of non-functional ovaries on three larval parasitoids of the alfalfa weevil: *Bathyplectes anurus* (Thomson), *B. curculionis* (Thomson) and *Bathyplectes stenostigma* (Thomson) (Hymenoptera: Ichneumonidae).

METHODS AND MATERIALS

B. curculionis pupae were reared from field collected host larvae. *B. anurus* adults and pupae were obtained from John K. Flessel, Ohio Agricultural Research and Development Center, Wooster, Ohio and Dr. B. C. Pass, University of Kentucky respectively, and *B. stenostigma* adults from Dr. Richard J. Dysart, Beneficial Insects Research Lab, Newark, Delaware. Cocoons were stored at 4°C until needed. They were then transferred to 20°C until eclosion. All parasitoids were kept at 20°C and 14 hours photophase and fed a 1:1 mixture of honey:water. The parasitoids were dissected in a water-filled, wax bottom petri dish and the condition of the ovaries was noted. The parasitoids were from 2–21 days old when dissected.

Acknowledgments: I am indebted to Dr. Richard J. Dysart, Dr. B. C. Pass and Mr. John K. Flessel for supplying parasitoids. I am especially indebted to my adviser Dr. David J. Horn for his ceaseless help throughout my graduate career.

RESULTS AND DISCUSSION

As with many ichneumons (Iwata 1961), the ovaries of the three *Bathyplectes* sp. are non-functional at eclosion. Within several hours the ovaries of normal females begin to elongate and individual oocytes become visible in the ovarioles. Within 24 hours mature eggs are present in the lateral oviducts. Dissections showed 14% of *B. anurus* (n = 14), 12% of *B. curculionis* (n = 50) and 9% of *B. stenostigma* (n = 9) females had ovaries that failed to mature. These ovaries never elongate and produce no eggs, rendering these females sterile.

Behaviorally those *B. anurus* and *B. curculionis* females with non-functional ovaries were attracted to host-damaged alfalfa, but failed to search the alfalfa or to attempt to oviposit in hosts they encountered. However, not all parasitoids failing to oviposit in hosts had non-functional ovaries, indicating that other factors besides functional ovaries are important in searching and ovipositional behavior.

The presence of up to 14% sterile females in each generation lowers the potential number of hosts that could be parasitized and may also lower the number of parasitoid progeny in the subsequent generation. Whether or not the presence of these sterile females has a detrimental impact on parasitoid numbers, it certainly has a detrimental effect on their ability to control the alfalfa weevil.

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INDEX TO SCIENTIFIC NAMES OF ANIMALS AND PLANTS VOLUME LXXXIV

Generic names begin with capital letters. New genera, species, subspecies, and varieties are printed in italics. The following are not indexed:

1. "Terrestrial mites of New York II. Mites in Birds' nests (Acarina)" by E. W. Baker, M. D. Delfinado, and M. J. Abbatiello. pp. 48–66.
2. "A review of the Mexican and Central American species of *Strangalia* Audinet-Serville (Coleoptera : Ceramlycidae)" by John A. Chemsak and E. G. Linsley. pp. 216–232.
3. "Terrestrial mites of New York. V." by Mercedes D. Delfinado. pp. 255–274.
4. "Notes on hypopi (Acarina) associated with bees and wasps (Hymenoptera)" by M. D. Delfinado and E. W. Baker. pp. 76–90.
5. "Terrestrial mites of New York (Acarina). IV. Cheyletidae and Cheyletiellidae" by M. D. Delfinado and A. A. Khaing-Fields. pp. 189–196.
6. "Terrestrial mites of New York-III. The family Scutacaridae (Acarina)" by M. D. Delfinado, E. W. Baker, and M. J. Abbatiello. pp. 106–145.

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CONTENTS

Developmental Anatomy of the Cephalopharyngeal Apparatus of the First and Second Instars of *Lucilia sericata* (Meigen) Larva (Diptera: Calliphoridae)

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Abstract: This paper examines the cephalopharyngeal apparatus of *Lucilia sericata* (Meigen) larva as it develops from egg to the third instar. Major emphasis is placed on the first transit stage between the first and second instar stages, and the second transit stage between the second and third instar stages. These two transit stages are subdivided into early, middle, and late transit substages. The late transit substage develops into the final cephalopharyngeal apparatus of its representative instar stage. The first transit stage occupies a very short period of time in relation to the entire second instar stage. The second transit stage is thought to have three substages, but only one substage is found. The substage found is the middle transit substage. A number of maggots are seen in the middle transit substage, but the early and late transit substages are not conspicuous.

INTRODUCTION

There have been many attempts to draw homologies between the cephalopharyngeal skeleton of cyclorraphan larvae and the mouthparts of a generalized adult insect. One of the first workers who developed a theory on the mouthparts of higher Diptera larvae was Weismann (1864). He stated that the mouth-hooks were not homologous with the mandibles of other insects but were newly evolved structures. Weismann theorized that the sclerotic remnants of the mandibles of *Musca* were shed after the first instar larva molted and were not found as distinct structure in later instars or the adults.

One of the most important works concerning the evolution of the head of dipteran larvae was that of de Meijere (1916). He presented a morphological study of a series of larval heads, starting with one which had a completely free head and ending with one in which the head was very much reduced. Throughout his investigation de Meijere homologized all the structures present and reasoned that the mouth-hooks could be homologized with the maxillae of more primitive Diptera. He concluded from his work that each structure must be considered separately since each proceeds at a different rate in the process of evolution. He indicated that a definite phylogenetic series could not be set up from the fly larvae he studied.

Probably the most prolific worker in the study of insect morphology was Snodgrass. His textbook, *Principles of Insect Morphology* (1935), is a classic

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representation of comparative insect morphology from an evolutionary standpoint. He summarized the work on the dipterous larvae, including his own work on the apple maggot (1924), and gave certain conclusions concerning the heads of the muscoid larvae. He inferred that the heads of the muscoid larvae were invaginated and that the cephalopharyngeal apparatus was derived from the walls of this invagination. He also believed that this structure was not homologous to the head capsule of other insects.

In a later publication by Snodgrass (1953) he described the structural disparity between the larva and the adult. He described the cephalopharyngeal apparatus of *Callitroga macellaria* as consisting of the mouth-hooks, labium, labrum, paraclypeal phragmata, clypeus and H-shaped sclerite. He also stated that the cephalopharyngeal apparatus was closely associated with the sucking pump of the larvae but theorized that the complex sucking apparatus must have been evolved first in the adult fly since the larvae of lower dipterous families have biting and chewing mouthparts.

Snodgrass pointed out that: "Structurally the fly larva is so different from the adult that it cannot itself be transformed without first being reconstructed, and that all of the tissue of the larval stage is dissolutioned, and the adult is newly generated from groups of undifferentiated cells that are present in the larva, but form no essential part of the larval organization. This development of metamorphic change is most conspicuous in the cyclorrhaphous families of Diptera while in the lower nematocerous flies metamorphic changes between larva and adult are less intense, and larval tissues may go over directly into adult tissues" (Snodgrass, 1953).

Probably the most extensive paper written on the cephalopharyngeal apparatus of Diptera larval heads was "The Evolution of the Head in the Larvae of the Diptera," by Cook in 1949. He presented a comparative morphological study of the heads of fly larvae, excluding the cyclorrhaphan, from an evolutionary viewpoint. Cook found that certain trends were in operation throughout the fly larvae, and thereby indicated the course by which the heads of the cyclorrhaphous dipterous larvae may have evolved.

Menees (1961) re-evaluated the work done by previous researchers on the embryonic and post embryonic stages of higher Diptera. He dealt specifically with the embryonic and post embryonic development of the gnathocephalon and its appendanges in *Lucilia sericata* Meigen.

In the first instar larva of *Lucilia sericata* Menees stated that the gnathocephalon and its appendages consisted of the following: (1) a pair of lightly sclerotized mouth-hooks thought to be modified maxillary appendage lobes; (2) a fused structure, the mandibles, which lies on top of the paraclypeal phragmata; and (3) the labiohypopharyngeal body, the anterior region of which is continuous with the paraclypeal phragmata and posterior end which articulates with the maxille. With regard to the structure labeled mandible, Menees pointed

out that it was with some reluctance that he applied this label, but felt the vestigal appendage lobes of the mandibular segment in the embryo best represented these fused structures.

In 1969, Roberts examined the structure of the mouth parts of Syrphid and Calypterate larvae in relation to their feeding habits. This type of observation of dipteran larvae in relationship to their feeding habits lends itself well to the study of the cephalopharyngeal apparatus since the apparatus is so instrumental in food intake. Since the cephalopharyngeal apparatus plays this important role in feeding, it is obvious that the variety of substrates which the different types of larvae feed upon will selectively modify the apparatus to best consume the substrate.

Probably no other part of insect anatomy has been subjected to such a diverse amount of interpretation as that of the cephalopharyngeal apparatus of dipteran larvae. Since this variety of interpretation of the cephalopharyngeal apparatus has been manifested with the third larval instar stage, then the lack of work done on the first and second instars lends itself to even a greater variety of interpretations because of its transit stages at each of the two molts.

MATERIALS AND METHODS

The eggs of *L. sericata* were obtained from the wild by placing a meat substrate in an area where the adults were observed. The adults readily oviposit on any type of meat; in this case, uncooked chicken parts were used as the substrate. To ensure that only the ova of *L. sericata* was cultured, the substrate was physically observed while the adults oviposited and only the eggs of *L. sericata* were collected for use. By observing the ovipositing adults, the process of separating other species of Diptera at a later time can essentially be eliminated.

After the eggs were collected, they were placed in a caged area for development. The caged area consisted of a series of smaller cages within a larger cage. The small cages were all the same size—61 cm by 25 cm by 30 cm. The large cage had an overall dimension of 120 cm by 75 cm by 60 cm. There were three small cages constructed of a low-grade lumber void of knotholes. The front of the cage was screened while the back was made of cloth with a sock 10 cm in diameter so that manipulation inside the cage could be provided. The large cage was screened on all sides and served to capture the adult flies in the event that they escaped from any of the three smaller cages.

The larvae were allowed to develop in each of the three smaller cages at staggered intervals to insure a constant supply of maggots by the adults ovipositing at different times. Care was taken to insure that the first generation of adults was cleared of all species other than *L. sericata*. "The Blowflies of North America" (Hall, 1948) was used to key to genus and species. After identifying 10 to 20 first generation adults, they were placed back into the cage—after the remainder of the first generation had been removed—and allowed to mate and

oviposit on the substrate provided. The larvae of the identified first generation adults were used as the experimental specimens.

Observations of live specimens were made with the aid of a wide-field microscope which had a maximum magnification of 300 times original size. No special arrangements of the food substrate were made for these observations. A portion of the original substrate containing approximately 10 maggots was placed in a petri dish to give easy manipulation under the microscope. This method of observation was used on all three instar stages, but because of their small size the cephalopharyngeal apparatus of the first instar was viewed under a compound scope after having been fixed on a slide. In order to obtain a detailed picture of the first instar apparatus, a magnification of 430 times was needed.

All pictures were taken with a Kodak 35 mm camera mounted on a Spencer compound microscope. The shutter speed was set at one twenty-fifth of a second, and Kodak 135 Tri-X or Panatomic black and white film was used.

RESULTS AND DISCUSSIONS

No attempt at proving or disproving any former theories that exist on the mouthparts of dipterous larvae was undertaken, but new concepts of the anatomy of the first and second instar stages of *Lucilia sericata* were discussed. Since the anatomy of the cephalopharyngeal apparatus changes with each molt, considerable discussion was on the newly formed cephalopharyngeal apparatus of the second and third instar stages.

The larva of *Lucilia sericata* is a typical apodous cyclorrhaphan maggot, approximately 14 mm long when mature. The body tapers only slightly from the posterior end to the cephalic segment. Segments two through eight are each provided with a complete encircling locomotory welt which has spines at the anterior margin. Segment nine may be either completely encircled or take the form of the following tenth, eleventh and twelfth segments which are void of spines on the dorsum, but have spines on the ventrolateral surfaces to form a half encircling welt used for locomotion. The anterior spiracles are located on the second segment laterally. The posterior spiracles are located on the twelfth segment and are a taxonomic characteristic of the third instar of that genus. The larval cuticle provides exoskeletal support and is shed with each molt.

There are three instar stages exhibited by *Lucilia sericata*. The first and second stages are both climaxed by molting, while the third stage terminates in the transformation to the puparium. During the two molts that occur in the larvae of *Lucilia sericata* the entire maggot's cuticle is cast along with the cephalopharyngeal apparatus (Figure 1). The successive second and third instars regenerate a new cuticle and cephalopharyngeal apparatus. The cuticle differs little in anatomy from one instar to the next, but the cephalopharyngeal apparatus is modified considerably among the three instar stages (Figures 2, 3 and 4). The

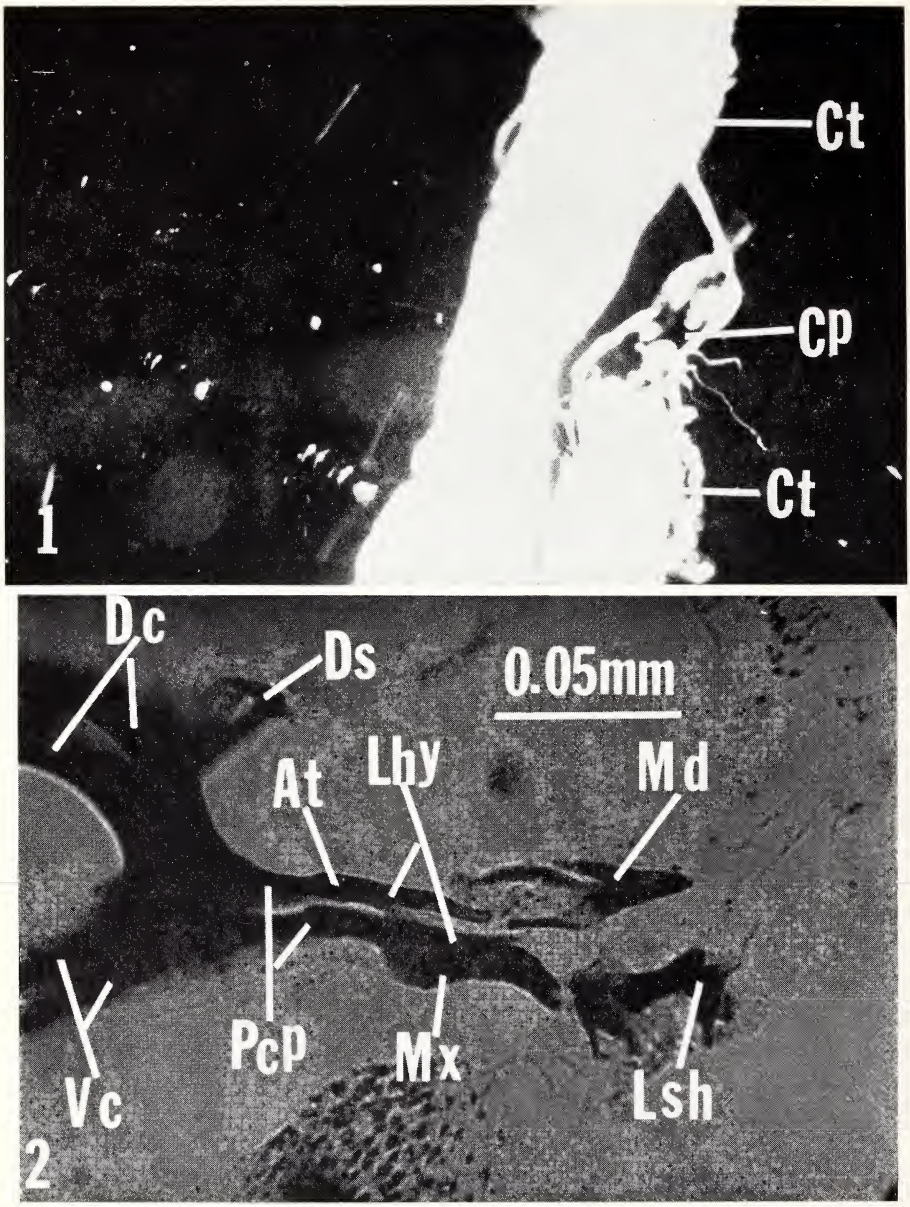


PLATE 1

FIG. 1. Cast cuticle and cephalopharyngeal apparatus of the first instar of *Lucilia sericata*. Cp, cephalopharyngeal apparatus; Ct, cuticle. 100×.

FIG. 2. Lateral view of the first instar cephalopharyngeal apparatus of *Lucilia sericata*. At, articulation between labio-hypopharyngeal body and paraclypeal phragmata; Dc, dorsal cornua; Ds, dorsal strap; Lhy, labio-hypopharyngeal body; Lsh, L-shaped hooks; Md, mandible; Mx, maxilla; Pcp, paraclypeal phragmata; Vc, ventral cornua. 430×.

cephalopharyngeal apparatus in all three instar stages is well adapted for locomotion.

The cephalopharyngeal apparatus of all three instars of *Lucilia sericata* taken on the same basic plan, being made up of maxilla, mandible, labio-hypopharyngeal body, paraclypeal phragma, and the cornua (Figures 2, 3, and 4). When the apparati are viewed from the posterior end, they display a conical shape due to the structure of the cornua. The maxilla, mandible and paraclypeal phragmata all vary in shape among the instars but are characteristic of each instar. The cornua differ little between the second and third instars, but the first instar has cornua that are C-shaped when viewed laterally (Figure 2).

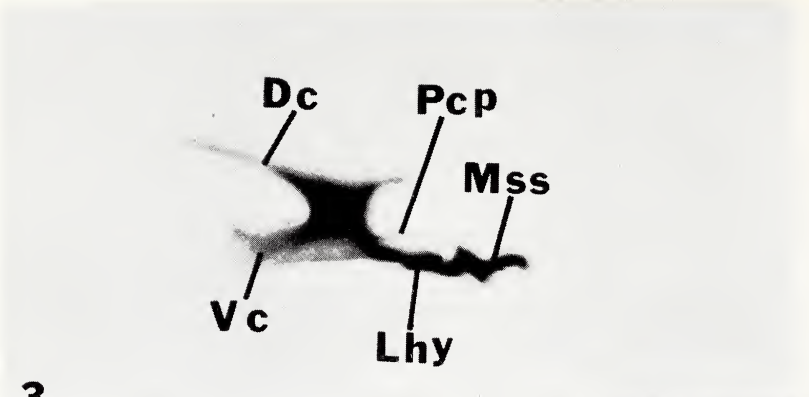
ANATOMY OF THE CEPHALOPHARYNGEAL APPARATUS— FIRST INSTAR STAGE

L-shaped hooks. In personal discussions with Menees, he indicated that during his observation in 1961 he failed to see these L-shaped hooks located at the anterior part of the cephalopharyngeal apparatus (Figure 2). Failure to recognize these structures does not seem surprising to me, since I also overlooked them for a considerable amount of time before noting their location. After one becomes aware of their relative location in reference to the cephalopharyngeal apparatus as a whole, observation of all first instar larvae of *Lucilia sericata* will reveal their presence.

The L-shaped hooks are visible as soon as the larvae hatch from the eggs, and retain their original shape from hatching until molting of the first instar larvae into second instar larvae. The actual shape of each of the two hooks is identical. They have a taper which starts at their posterior end (see Figure 2) and increases in size with progression toward the 90 degree angle made at the anterior end—the anterior and posterior ends of the hooks are in reference to the anterior and posterior end of the cephalopharyngeal apparatus as a whole. The short portion of the L-shaped hooks points toward the ventral side of the maggot and is also tapered to a point.

The design of these hooks is simple, but the nature in which the larvae use them does not necessitate any complex device. The hooks are used by the first instar for locomotion purposes only, and are thrust into the substrate not by individual muscular action but by the maggot manipulating its entire anterior body in a vertical downward motion, hence the L-shaped hooks serve to anchor the anterior end as the posterior end is pulled forward by rhythmic muscle contraction of the body segments.

Mandible. The mandible constitutes the apex of the A-shaped anterior end of the cephalopharyngeal apparatus of the first instars of *Lucilia sericata* (Figure 2). The mandible has an overall length of 0.04 mm and is 0.03 mm wide at its widest point. When viewed from the ventral side (Figure 5), the mandible appears to be rod-shaped at its anterior end. The posterior end, however, has



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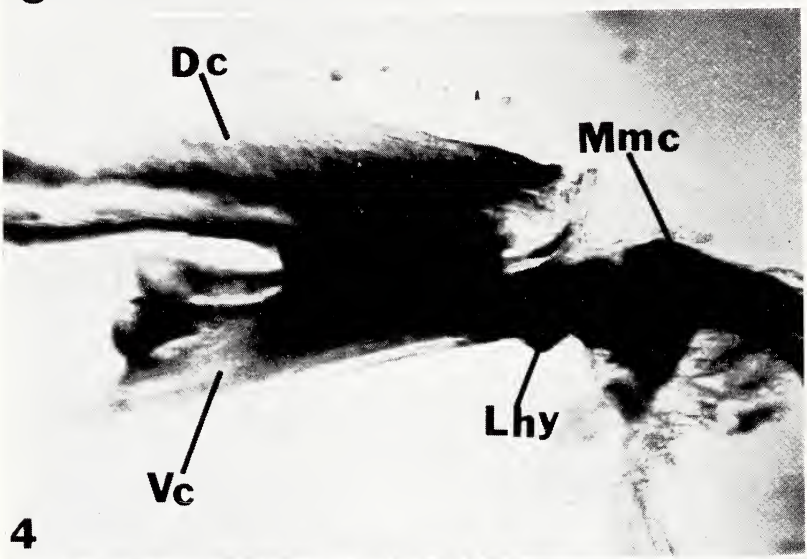

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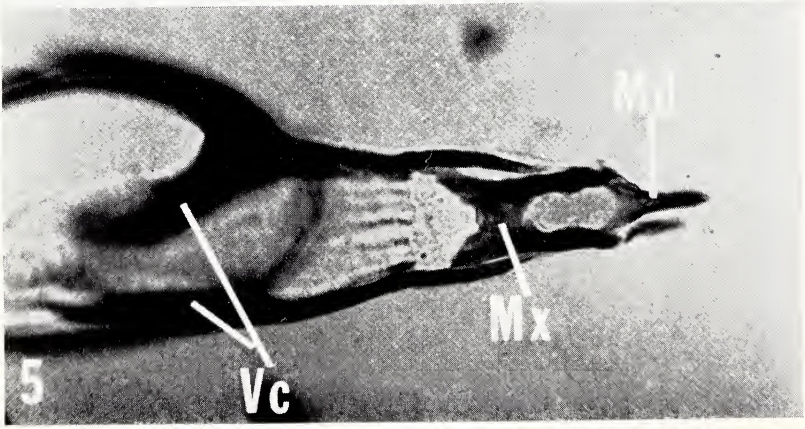

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two projections that extend in a ventrolateral direction from the rod-shaped anterior structure and these two posterior projections articulate loosely with the labio-hypopharyngeal body (Figure 2). It is at this articulation point that the mandible obtains its widest dimension. As the larvae feed, the mandible can be observed flickering up and down to facilitate the movement of the food substrate toward the area of maxilla. Therefore, the mandible plays an important role in the feeding process but makes a poor contribution to locomotion.

In his publication on the gnathocephalon in the larvae of higher Diptera (1961), Menees illustrates the mandible as being located behind the maxilla, but it is in fact in front of the maxilla forming the apex to the A-shaped structure of the cephalopharyngeal apparatus (Figure 5).

Labio-hypopharyngeal body. At its posterior end, the mandible articulates with two independent rod-like structures labeled the labio-hypopharyngeal body (Figure 2). The labio-hypopharyngeal body has an overall length of 0.05 mm from its anterior articulation with the mandible to its posterior articulation with the paraclypeal phragmata (Figure 2). In the first instar of *L. sericata* the labio-hypopharyngeal body has no connection between the two rod-like structures that are parallel to one another. The articulation that the labio-hypopharyngeal body makes with the paraclypeal phragmata is very close. This articulation is indicated by a fine line that separates the two structures on an angle of approximately 45 degrees (Figure 2).

The labio-hypopharyngeal body does not display much movement as the larvae move about and feed, but does flex slightly at its anterior end. The function of the labio-pharyngeal body is to transfer force anteriorly as pressure is applied to posterior parts of the cephalopharyngeal apparatus.

Paraclypeal phragmata. The paraclypeal phragmata are anterior extensions of the ventral cornua, and the two structures combined have an overall length of 0.15 mm (Figure 2). The length of the paraclypeal phragmata alone is not indicated because there is no apparent separation that can be made between it and the ventral cornua. The distal end of the paraclypeal phragma terminates by articulating with the previously described labio-hypopharyngeal body. The

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PLATE 2

Fig. 3. Lateral view of the first instar cephalopharyngeal apparatus of *L. sericata*. Dc, dorsal cornua; Lhy, labio-hypopharyngeal body; Mss, M-shaped structure; Pcp, paraclypeal phragmata; Vc, ventral cornua. 100×.

Fig. 4. Lateral view of the third instar cephalopharyngeal apparatus of *L. sericata*. Dc, dorsal cornua; Lhy, labio-hypopharyngeal body; Mmc, maxillary-mandibular complex; Vc, ventral cornua. 100×.

Fig. 5. Ventral view of the first instar cephalopharyngeal apparatus of *L. sericata*. Md, mandible; Mx, maxillae; Vc, ventral cornua. 430×.

role the paraclypeal phragmata play in locomotion is not so dramatic as the L-shaped hooks, mandible, and the labio-hypopharyngeal body. The phragmata participate in the transfer anteriorly of any force placed on the cornua directly to the labio-hypopharyngeal body.

Since the paraclypeal phragmata articulate with the labio-hypopharyngeal body and there are two rod-like structures that make up the labio-hypopharyngeal body, then it follows that there should be two points of articulation which necessitate two extensions of the ventral cornua. This double extension of the ventral cornua constitutes the paraclypeal phragmata.

Maxilla. The maxilla is the most active structure of the cephalopharyngeal apparatus, located just beneath the paraclypeal phragmata, has overall length of 0.05 mm. The anterior end of the maxilla is slightly curved ventrally in order to rake food material into the oral cavity (Figure 2). When viewed laterally, the maxilla extends parallel and ventral to the paraclypeal phragmata. It also protrudes beyond the paraclypeal phragmata by approximately 0.02 mm. A ventral view of the maxilla (Figure 5) shows two rod-like structures extending anteriorly. It is these rod-like structures that take on the ventrally curved appearance when viewed laterally. The two rod-like structures fuse together just posterior of their midline (Figure 5). The posterior end of each rod flares in a lateral direction. The posterior connection of the two rods of the maxilla gives the structure a characteristic H-shaped appearance when viewed either dorsally or ventrally.

Cornua. The dorsal and ventral cornua are fused medianly giving a C-shaped appearance when viewed laterally. There is a dorsal strap that connects the two dorsal cornua together (Figure 2). The two ventral cornua have no such strap-like structure and are in fact completely independent of each other.

The cornua make their main contribution to larval feeding by serving as the site for the origin of the maxilla, mandible, and cibarial mucles that are all instrumental in feeding. While at the same time the actions of these cephalopharyngeal muscles are also responsible for some larval locomotion.

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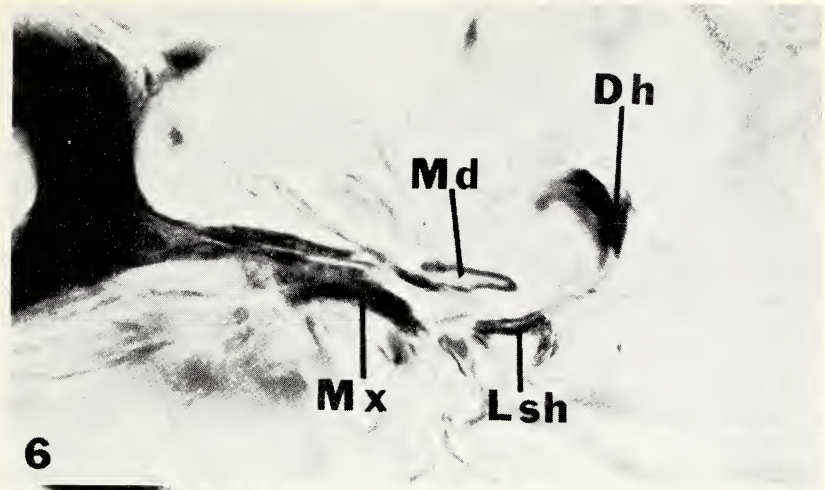
PLATE 3

FIG. 6. Lateral view of early transit substage during first transit stage. Dh, dorsal hooks; Lsh, L-shaped hooks; Md, mandible; Mx, maxillae. 430×.

FIG. 7. Lateral view of middle transit substage during first transit stage. Dh, dorsal hooks; Ls, lateral sclerite; Lsh, L-shaped hooks; Mx, maxillae. 430×.

FIG. 8. Lateral view of late transit substage during first transit stage. Ls, lateral sclerite; Lhy, labio-hypopharyngeal body; Mss, M-shaped structure; Pcp, paraclypeal phragma. 430×.



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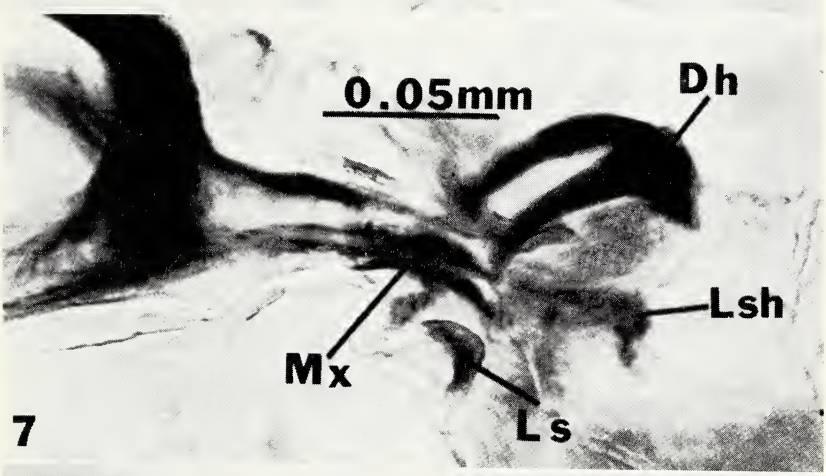

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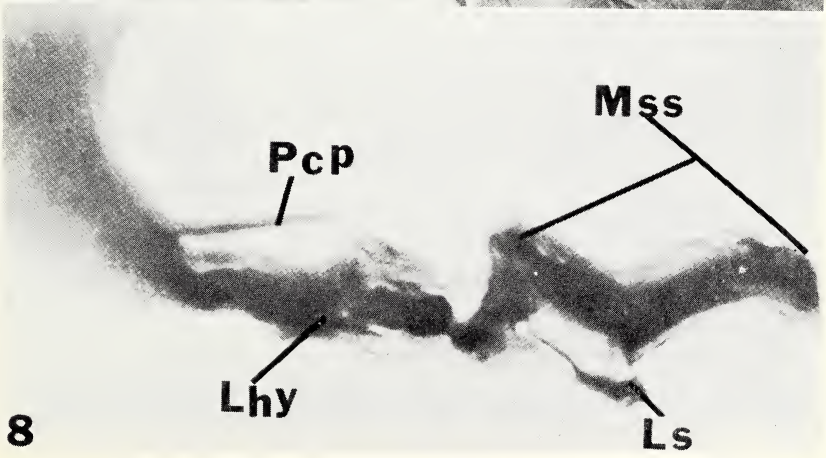

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ANATOMY OF THE CEPHALOPHARYNGEAL APPARATUS— FIRST TRANSIT STAGE AND SECOND INSTAR

The transition from the first instar to the second instar necessitates a molt which casts the larval cuticle and cephalopharyngeal apparatus during the process (Figure 1). The time required from hatching to first molt, of course, varies with the physical environment but under laboratory conditions, this time is approximately 40 hours. Since the molting process requires the regeneration of a new cephalopharyngeal apparatus, then it follows that the newly formed apparatus in the early second instar can potentially take on a different anatomical shape. But no matter what anatomical shape evolves from the newly forming cephalopharyngeal apparatus, its function of feeding and locomotion is retained.

The ultimate shape obtained by the cephalopharyngeal apparatus of the second instar is illustrated in Figure 3, and it contains all the characteristic subunits described in the discussion of the first instar anatomy. To obtain its final second instar shape the apparatus must first undergo a transit stage. This transit stage is differentiated into three substages—early, middle, and late.

Early transit substage. At first observation the early transit substage between the first and second instars could be mistaken for the cephalopharyngeal apparatus of the first instar. The early transit substage has an overall appearance that is characteristic of the first instar apparatus with the exception of the lateral sclerites on each side of the maxilla and the more conspicuous dorsal hooks forming above the mandible (Figures 6 and 9). These two exceptions are the only differences between the cephalopharyngeal apparatus of the first instar (Figures 2 and 5) and the early transit substage (Figures 6 and 9).

Middle transit substage. During this substage the entire cephalopharyngeal apparatus has enlarged. The dorsal hooks have migrated down as well as enlarged (Figure 7). The dorsal hooks have also begun to develop a spur that protrudes from the basal area which will later give an M-shaped appearance in the late transit substage (Figure 8). The L-shaped hooks are still visible anterior and ventral to the dorsal hooks (Figure 7). These hooks maintain almost the

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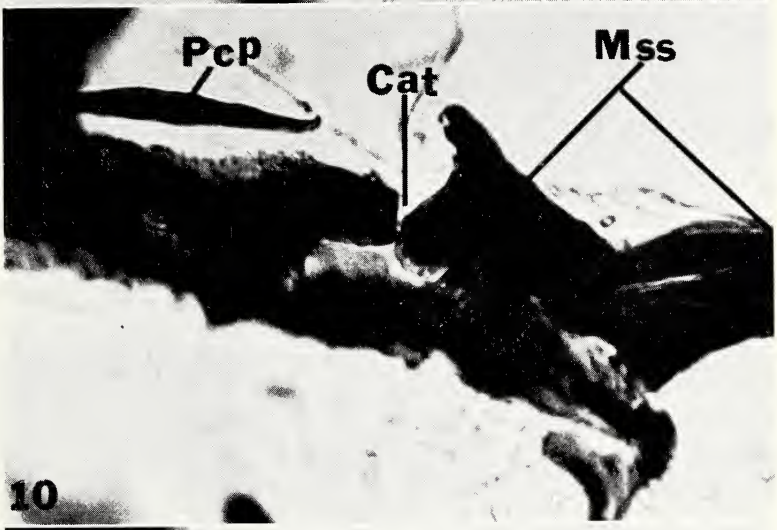
PLATE 4

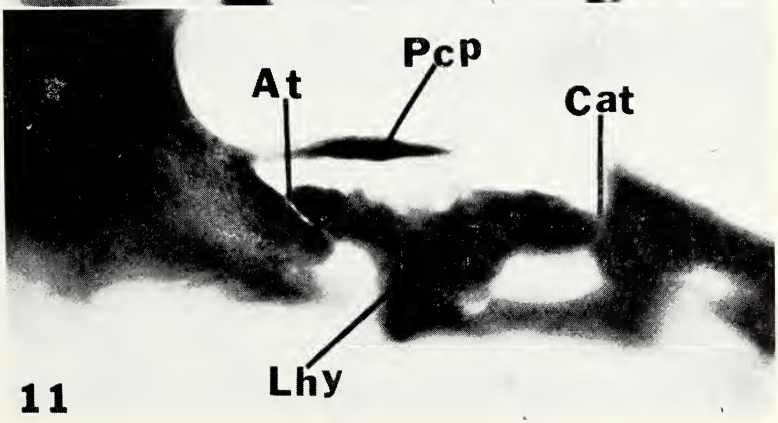
FIG. 9. Ventral view of early transit substage during first transit stage. Dh, dorsal hooks; Ls, lateral sclerite; Lsh, L-shaped hooks; Md, mandible; Mx, maxillae. 430×.

FIG. 10. Lateral view of the second instar cephalopharyngeal apparatus showing M-shaped structure and condylar articulation. Cat, condylar articulation; Mss, M-shaped structure; Pcp, paraclypeal phragmata. 430×.

FIG. 11. Lateral view of second instar cephalopharyngeal apparatus showing articulation of labio-hypopharyngeal body with the M-shaped structure and ventral cornua. At, posterior articulation; Cat, condylar articulation; Lhy, labio-hypopharyngeal body; Pcp, paraclypeal phragmata. 430×.


Mx
Dh
Lsh
Ls
Mx


Pcp
Cat
Mss
10


At
Pcp
Cat
Lhy
11

same appearance in this substage as they displayed in the first instar apparatus (Figure 2). The middle transit substage also shows the paraclypeal phragma and the labio-hypopharyngeal body articulating with one another as they did in the cephalopharyngeal apparatus of the first instar (Figure 2). The origin of the paraclypeal phragma is at the ventral cornua. The lateral sclerites have merged toward the midline of the apparatus and are located just below the maxilla (Figure 7). The cornua in this transit substage still maintains the same C-shaped configuration that was characteristic of the first instar.

Late transit substage and second instar stage. This substage of the transit series shows the major changes developing in formulating the final second instar cephalopharyngeal apparatus. Besides continuing to enlarge the apparatus now starts to fuse together. The dorsal hooks have migrated ventral to their maximum at this point and the spur is developing further in a posterior direction. The lateral sclerites are now starting to fuse with the developing spur and will form the M-shaped structure of the cephalopharyngeal apparatus in the second instar (Figure 8).

At the same time the structure formerly called the maxilla in the first instar will become more massive and form an articulation with the M-shaped structure (Figure 10). This articulation is condylar. The structure formerly called the maxilla in the first instar maintains its H-shaped appearance when viewed from the dorsal or ventral sides, but no longer forms the function of the maxilla. With functional transformation from maxilla to an articulation piece between the M-shaped hooks and the ventral cornua (Figure 11), this structure, called H-piece by some workers, will be called the labio-hypopharyngeal body here to save parity. The articulation that the labio-hypopharyngeal body makes with the ventral cornua allows restricted movement. The restriction placed on this articulation is due to the angle of the articulation itself, which allows movement in a short oblique plane (Figure 11).

The paraclypeal phragmata are located just dorsal to the labio-hypopharyngeal body in the late transit substage and second instar stage. The paraclypeal phragma does not undergo any modification during the transit substages and

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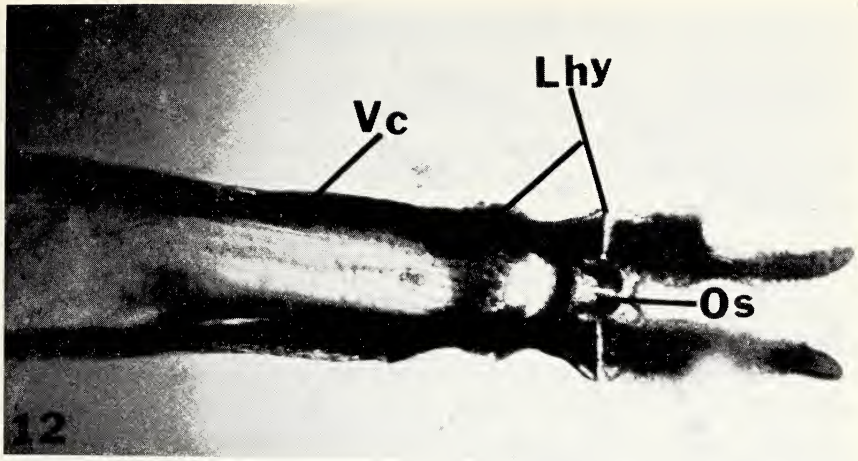
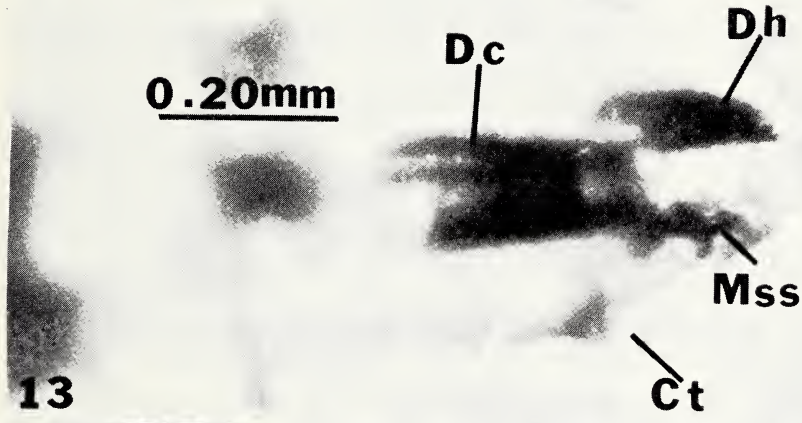
PLATE 5

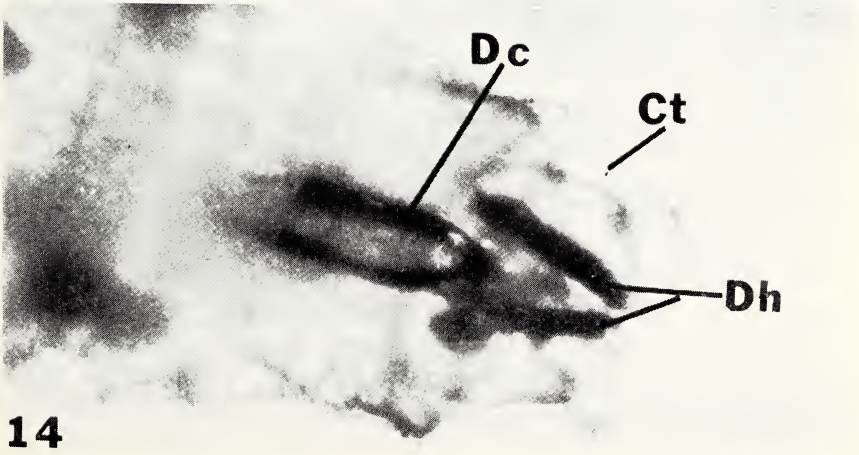
FIG. 12. Ventral view of the third instar cephalopharyngeal apparatus showing oral sclerite anterior to the labio-hypopharyngeal body. Lhy, labio-hypopharyngeal body; Os, oral sclerite; Vc, ventral cornua. 100×.

FIG. 13. Lateral view through intact larva of the probable middle transit substage during the second transit stage. Ct, cuticle; Dc, dorsal cornua; Dh, dorsal hooks; Mss, M-shaped structure. 100×.

FIG. 14. Dorsal view through intact larva of the probable middle transit substage during the second transit stage. Ct, cuticle; Dc, dorsal cornua; Dh, dorsal hooks. 100×.


Lhy
Vc
Os
12


0.20mm
Dc
Dh
Mss
Ct
13


Dc
Ct
Dh
14

remains in its same position while the anterior end of the ventral cornua enlarges to form the restricted articulation with the labio-hypopharyngeal body. In previous discussion of the first instar cephalopharyngeal apparatus, the labio-hypopharyngeal body formed a close articulation with the paraclypeal phragma (Figure 2). However, in the second instar stage this articulation is not apparent, and the synthesis of the labio-hypopharyngeal body is produced by conversion of what appeared to be the maxilla in the first instar stage.

Up to and including the middle transit substage, the two strutcures, referred to as the L-shaped hooks and the mandible, are conspicuous (Figure 7). When the transformation into the late transit substage begins, these two structures are no longer visible. Speculation on the author's part is somewhat mixed. The structures referred to as the L-shaped hook cannot be accounted for in the late transit stage as a newly modified structure, but may fuse with the spur of the dorsal hooks and aid in the formation of the M-shaped structure that is characteristic of the second instar cephalopharyngeal apparatus. The structure previously referred to as the mandible may be modified to form the oral sclerite which can be seen developing in the late transit substage and becomes more conspicuous in the final instar stages (Figure 12).

The C-shaped cornua that have been characteristic of all stages before the late transit stage, undergo considerable modification from their original shape. The two dorsal and ventral cornua enlarge both in length and height. The dorsal cornua are also connected by a strap, as in the first instar cephalopharyngeal apparatus. The modification of the strap in the second instar is one of size and not function or transformation.

ANATOMY OF THE CEPHALOPHARYNGEAL APPARATUS— SECOND TRANSIT STAGE AND THIRD INSTAR

Like the previous stage the second instar stage casts its cephalopharyngeal apparatus along with the cuticle. This process then necessitates the regeneration of a new apparatus along with the cuticle in the third instar stage. The initial regeneration process does not immediately take on the appearance of the final third instar cephalopharyngeal apparatus. A transit stage as in the second instar also takes place in the third instar; however, this third instar transit stage is not as extensive as that of the second instar. Both transit stages occur very rapidly from start to finish in development, but the transit stage between the second and third instar seems to have one dominant stage (Figures 13 and 14).

While trying to collect specimens of the second transit stage the only substage collected was the dominant stage (Figures 13 and 14). The author believes that more than one substage exists. There are perhaps three substages, just as in the first transit stage. If three substages do indeed exist in the second transit stage then the obvious question is—what substage is indicated by Figures 13 and 14? This substage is possibly the middle transit substage since the dorsal

hooks are well developed and the cephalopharyngeal apparatus, excluding the hooks, has the appearance of the final apparatus of the second instar stage. The substage preceding the middle transit substage, possibly takes on a shape similar to the middle substage except for the dorsal hooks which are thought to be reduced. The late transit substage would be indicated when the dorsal hooks migrate down and become loosely attached by fusion to the M-shaped structures. The author believes that stimulus for downward migration of the dorsal hooks is caused by the force of gravity or a hormonal response.

During these transit stages the cephalopharyngeal apparatus, although not fully developed, is able to afford the maggot good mobility. The dorsal hooks have not yet fused to form the final apparatus, but since the initial transit substage has the appearance of the previous instars' cephalopharyngeal apparatus, locomotion is not reduced during the transit stages. The locomotion is, however, greatly enhanced once the final apparatus has been developed.

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Two New Species of *Perdita* from Arizona and Utah (Hymenoptera, Andrenidae)

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Abstract: *Perdita* **eickworti** n. sp. is described from Arizona and *P.* **cornishiana** n. sp. from Utah. The types will be deposited in the collection of Cornell University, Ithaca. A note on the occurrence of *Perdita foveata* in Florida is also included.

Perdita (*Hexaperdita*) *foveata foveata* Timberlake

New Record.—Four females, 2 males, Arcadia, Desoto County, Florida, at flowers of *Coreopsis*, April 27, 1974 (G. Eickwort); 5 males, St. Petersburg, Pinellas County, April 9, 1974 (G. and K. Eickwort).

These specimens are almost entirely dark. One female has a whitish mark on the middle of the clypeus, and two other specimens have a white dot on each side of the hind margin of the pronotum.

Perdita (*Perdita*) **cornishiana**, n. sp.

The male of **cornishiana** runs in the key to the *Octomaculata* Group (Timberlake, 1960) to *durangoensis*, couplet 176. It differs in somewhat paler yellow face marks, with inner margin of the subantennal plates dark green only on the lower two-thirds, legs yellow in front from the trochanters to tarsi, except hind tibiae and tarsi entirely dark, and abdominal bands more narrowly interrupted, with that on second tergite widened at outer ends and almost reaching lateral margins.

Male.—Head and thorax dark green, propodeum more bluish. Mandibles except apex, labrum and face below level of antennae rather pale yellow, but somewhat less than lower two-thirds of inner margin of subantennal plates broadly dark green. Supraclypeal mark high as wide, slightly narrowed above, with small median notch. Lateral marks ending obliquely and acutely at anterior end of foveae. Thorax dark except narrow rim of collar, spot on each side of hind margin of pronotum and irregular outer margin of tubercles yellow. Abdomen black, with rather narrowly interrupted yellow bands on tergites 2 to 4, that on tergite 2 least interrupted, widened at outer ends and almost reaching lateral margins; apical lobe of tergite 7 rufotestaceous. Scape of antennae yellow, with black mark above, not reaching base, flagellum dull yellow beneath and dark above. Legs yellow, with front and middle femora and tibiae and hind femora mostly black behind, but hind tibiae and tarsi entirely dark. Proboscis fuscous at base, with galeae and glossa testaceous. Tegulae subhyaline, yellow at base. Wings dusky hyaline, nervures fucous, subcosta and margins of stigma darker, with disk of stigma narrowly pale.

Acknowledgment: Collection of specimens and publication of the manuscript were supported by National Science Foundation Grant No. GB-35954 (G. C. Eickwort, principal investigator).

Head large, broader than thorax and broader than long; cheeks receding, about half as wide as eyes, and broad at temple; occiput broadly and shallowly concave. Ocelli in broad triangle, posterior pair slightly less than their distance apart from occipital margin and somewhat more distant from margin of eyes. Facial foveae small and oval, close to margin of eyes. Antennae inserted below middle of face, scapes not reaching level of ocelli, flagellum subclavate, with middle joints as thick as long. Face below level of antennae moderately convex from side to side, with disk of clypeus broader than high, broadly truncate at summit, and with lateral extension narrowly visible in frontal aspect. Subantennal plates oval, pointed below, somewhat less than twice as long as wide. Antennal sockets about equidistant from each other and margin of eyes. Proboscis nearly twice as long as head, with galeae extremely long and slender. Pterostigma less than half as wide as first submarginal cell; marginal cell as long as stigma, longer beyond than beneath stigma, with metacarpus nearly twice as long as apical truncation. Frons and vertex microscopically granular, opaque and impunctate. Face below level of antennae comparatively smooth, shining and almost impunctate. Mesonotum minutely tessellate, more shining than frons, and with sparse, minute setigerous punctures. Metapleura and propodeum minutely tessellate, moderately shining with pleura punctured toward sternum. Pubescence white, fine and erect, moderately long and dense on cheeks, longer and thin on vertex, and becoming short, fine and subdepressed on each side of face between foveae and antennal sockets. Mesonotum with rather short, thin, erect hair, and apical fimbria on abdomen thin.

Length, about 6 mm; anterior wing, 4.6 mm; width of abdomen, 1.7 mm.

Holotype male, Cornish, Cache County, Utah, July 27, 1973 (G. Eickwort and G. Bohart)

Perdita (*Perdita*) **eickworti**, n. sp.

This species is placed confidently in the *Sphaeralceae* Group, and in the key (Timberlake, 1964) the female runs to couplet 110 and would go on to the next couplet with *punctulata* and *covilleae*, except that the face markings are trifurcate, with the dark color descending on each side of the supraclypeal area to unite with a dark mark on each side of the clypeus.

Female.—Head and thorax dark green, frons somewhat bronzy. Mandibles (except reddish tips), labrum, clypeus, lateral marks (ending bluntly against foveae and briefly intruding between them and eyes) and supraclypeal mark (intruding bluntly between antennal sockets) clear but rather pale yellow. Green of frons descending on each side of supraclypeal area, but more blackly, and uniting evenly with dark mark on each side of upper half of disk of clypeus, thus forming trifurcate design. Pronotum and tubercles yellow, except dark mark on lower part of flanks. Abdomen yellow with four moderately wide fuscous bands at junction of segments. Scape of antennae yellow, pedicel and flagellum fuscous, but narrowly yellow beneath. Legs including coxae yellow, but streak on middle tibiae behind, mark at apex of hind femora above and hind tibiae and tarsi fuscous.

Head much broader than long, with cheeks strongly receding, slightly more than half as wide as eyes. Posterior ocelli somewhat closer to margin of eyes than to each other. Frontal foveae deeply impressed, close to margin of eyes, about five times longer than wide and reaching from upper level of antennal sockets somewhat more than halfway to level of anterior ocellus. Antennae inserted below middle of face, with antennal sockets closer to each other than to margin of eyes; scape slender, flagellum slightly clavate, with middle joints as long as thick. Face below level of antennae gently convex from side to side; supraclypeal mark no higher than wide, but part below level of antennae broader than long. Disk of clypeus broader than high, truncate at summit, with lateral extensions narrowly reflexed and visible in frontal aspect. Mandibles apparently simple and not reaching far

margin of labrum. Proboscis moderately long, mainly concealed in type. Pterostigma half as wide as first submarginal cell and emitting radius somewhat beyond middle; marginal cell about equal beneath and beyond stigma, but metacarpus distinctly longer than apical truncation. Pygidial plate broader at base than long, with sides converging to rather narrow, slightly notched apex.

Frons and vertex minutely tessellate, moderately dull and with scattered minute punctures; face below level of antennae smooth, with shallow, small punctures on clypeus and supraclypeal area. Mesonotum polished, minutely and sparsely punctured, but more closely and distinctly on scutellar and prescutellar areas. Mesopleura polished, with minute, well-separated punctures. Pubescence white, short, fine and thin, short and erect on mesonotum but more dense on prescutellar area. Hair of front coxae long, but thin, and scopal hair of hind legs somewhat longer than greatest width of tibiae.

Length, 4 mm; anterior wing, 2.8 mm; width of abdomen, 1.3 mm.

Holotype female, Joseph City, Navajo County, Arizona, July 31, 1973 (G. C. Eickwort).

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Variability and Absence of Sexual Dimorphism in the Sounds of *Cycnia tenera* Hübner (Lepidoptera: Arctiidae)

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Abstract: The arctiid, *Cycnia tenera* Hübner exhibits no sexual dimorphism in six out of seven acoustic parameters measured in the sounds emitted by five male and five female specimens. The parameters reveal an extremely high level of variability for both male and female emissions. These observations suggest that calling or courtship signalling are not likely roles for the sounds of *C. tenera* but do not rule out the possibility of other intraspecific communicative functions.

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INTRODUCTION

Although it has been known since 1864 (Laboulbène) that certain arctiid moths will emit sounds, quantitative analyses of the emissions have been scarce (Rothschild and Haskell, 1966; Blest et al., 1963). It is now generally held that arctiid sounds serve a role in anti-predator defense (Dunning and Roeder, 1965; Dunning, 1968), but the possibility that the sounds operate as calling or courtship signals has never been seriously examined. Forbes and Franclemont (1957) noted the absence of sexual dimorphism in the external morphology of the sound-producing organs (tymbals) of a number of arctiid species but did not investigate the sounds produced by either male or female specimens.

Cycnia tenera Hübner is one of a number of Nearctic arctiids that will produce sounds under tactile or acoustic stimuli (Fullard and Fenton, in press). The tymbal of *C. tenera* possesses a well-defined row of microtymbals that is positioned on a ridge along the anterior edge of the sclerite. Fenton and Roeder (1974) present a comparative survey of some arctiid tymbals including those of *C. tenera*.

In this study, the sounds of male and female *C. tenera* were analyzed with reference to certain acoustic parameters to determine the degree of variability of the sounds and whether there were any differences due to sexual dimorphism.

METHODS AND MATERIALS

Specimens of *C. tenera* were collected from June 7 to July 17, 1975 from four ultraviolet light traps at the Queen's University Biology Station located

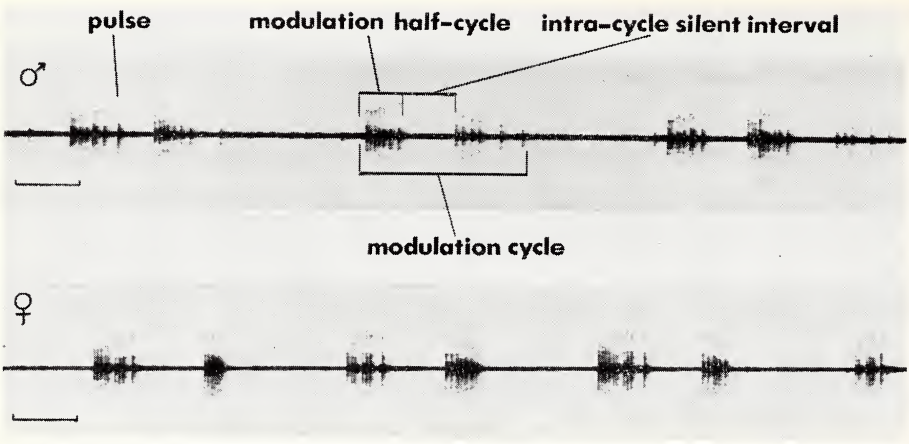

FIG. 1. Oscillographic traces of the emissions of male (top) and female (bottom) *C. tenera*. The acoustical parameters used in the study are illustrated for the male emission. Time scale for both oscillograms is 10 msec.

near Chaffey's Locks, Ontario, Canada. Moths were recorded immediately following capture. The specimens were placed individually 2 cm from a Brüel and Kjaer (B&K) ¼-inch condenser microphone Type 4135 and stimulated to produce sounds by holding the moth's upraised wings between thumb and forefinger and lightly touching the insect's abdomen. It was possible, in this way, to obtain sustained emissions of up to 30 sec in length after the initial stimulus was applied. Sounds produced by moths restrained in this fashion appeared no different than those from specimens recorded in stationary flight with their wings free. The method employed in this study, however, did allow for greater accuracy of intensity measurements.

The signal was amplified by a B&K Measuring Amplifier Type 2606 and then fed into an Ampex Instrumentation Recorder (PR-500) using a tape speed of 76 cps. The signal was later analyzed by playing it back at reduced tape speed (2.4 cps) into a Tektronix 5103N Storage Oscilloscope.

The acoustic parameters measured in this study include ones previously described by Blest et al. (1963) and Dunning (1966, 1968) and are illustrated in Fig. 1. The following measurements were used: 1. duration (msec) of modulation half-cycle (MHC); 2. duration (msec) of intra-cycle silent interval (ICSI); 3. duration (msec) of modulation cycle (MC); 4. pulses per modulation half-cycle (P/MHC); 5. pulse repetition rate (pulses per second) (P/SEC); 6. dominant frequency (kHz) (DFREQ) and; 7. intensity (dB) (linear setting) (re .0002 dynes/cm^2) (INT).

Intensities were measured at 2 cm using the B&K Measuring Amplifier and recorded as dB SPL (re .0002 dynes/cm^2).

Table 1. Measurements of acoustic parameters in male and female *C. tenera*, coefficients of variation and results of single classification analysis of variance.

Parameter	Average Values		Coefficients of Variation		
	male	female	male	female	F_s-value[2]
MHC (msec)	5.0 ± 1.3[1] (5)	5.5 ± 0.7 (5)	26.0	12.7	0.47
ICSI (msec)	6.2 ± 1.5 (5)	6.3 ± 2.2 (5)	24.2	34.9	0
MC (msec)	17.4 ± 2.1 (5)	19.7 ± 2.9 (5)	12.1	14.7	1.94
P/MHC	8.4 ± 2.4 (5)	6.9 ± 1.5 (5)	28.6	21.7	1.35
P/SEC	1677.9 ± 145.5 (5)	1316.3 ± 245.7 (5)	8.7	18.7	10.48[3]
DFREQ (kHz)	57.8 ± 18.9 (5)	48.2 ± 13.2 (5)	32.7	28.6	0.84
INT (dB)	69.8 ± 2.6 (5)	66.3 ± 5.7 (3)	3.7	8.6	1.47

[1] Mean ± S.D. of mean. Figures in parentheses indicate sample size.
[2] Probability = 5%.
[3] Significant.

Dominant frequencies were determined from frequency spectra produced from continuous emissions played into a Tektronix Storage Oscilloscope Type 564 equipped with a Type 3L5 Frequency Spectrum Analyzer. The analyzer was calibrated before each run using an Exact Model 126 VCF/Sweep Signal Generator set at 50 kHz.

The sounds of five males and five females were analyzed with reference to these parameters. The average values for each parameter from ten complete modulation cycles of each specimen were then used in a single classification analysis of variance (Sokal and Rohlf, 1969) to determine any differences due to sex.

To test for signal variability in the aforementioned parameters, coefficients of variation were computed for the values of both male and female emissions.

RESULTS

The parametric measurements, coefficients of variation and F_s values for the male and female sounds are presented in Table 1. The results of the analysis of variance test reveal no differences in any of the parameters studied except for pulse repetition rates where males exhibited slightly higher rates than

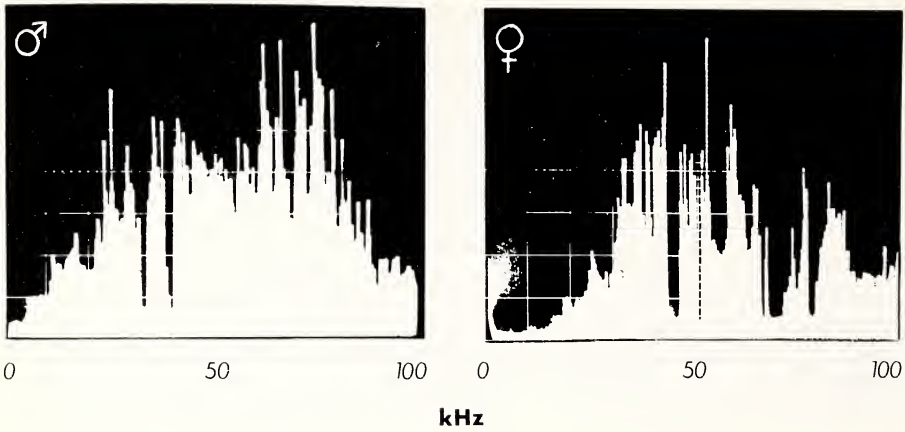

FIG. 2. Typical frequency spectra of continuous emissions of male (left) and female (right) *C. tenera*. Abscissa represents frequency in kHz and ordinate represents relative intensity.

females. There were no significant differences in the average intensities or dominant frequencies generated by either sex.

The coefficients of variation indicate an extremely high level of variability in all of the parameters surveyed for both male and female specimens. The highest values recorded were for DFREQ (male) and ICSI (female) and the lowest was for INT (male and female).

Typical frequency spectra from male and female moths are illustrated in Fig. 2. The frequencies emitted by the insects are almost completely ultrasonic and are broad-band with considerable energies contained in frequencies from 30 to 70 kHz. A small proportion of the frequencies generated is below 20 kHz (sonic) and renders the emission faintly audible to the unaided human ear as a soft buzzing sound.

DISCUSSION

The original assumption of Laboulbène (1864) that arctiid sounds were courtship signals seems unlikely in the case of *C. tenera*. Courtship songs in female arthropods are unknown (Alexander, 1967) and phonoresponses (i.e. "Agreement Songs" of Orthoptera (Dumortier, 1963)) are usually produced in response to male signals and differ in a number of ways (e.g. pulse-rate, intensity, duration) from the male stridulation. The existence of acoustically similar signals in both male and female *C. tenera* does not fit well with Dumortier's observations.

Several other factors also contradict a sexual role for the sounds of *C. tenera*. The emissions are generally low in intensity compared with other calling insects

(e.g. *Metrioptera sphagnorum* F. Walker (Orthoptera: Tettigoniidae): 87 dB(A) at 5 cm (Morris et al., 1975)) and would not function well as long-range calling signals. This, in itself, would not preclude the possibility that the sounds are used as short-range signals; however, the absence of sound-production in copulating pairs of other arctiid species (Dunning, 1966; personal observation) suggests that arctiids do not use their sounds in close proximity encounters.

The extremely high variability exhibited by the acoustic parameters of *C. tenera* emissions is also incongruous with a sexual function. In contrast, the male calling song of *Conocephalus nigropleurum* Bruner (Orthoptera: Tettigoniidae) possesses very low variability and this appears to be an important factor in eliciting a phonotactic response in receptive females (G. K. Morris, pers. comm.).

Although sexual signalling appears unlikely in the sounds of *C. tenera*, the possibility of other intraspecific communicative functions cannot be dismissed. If the arctiid sound is a warning signal for predators, the evolution of secondary responses in conspecifics (e.g. alarm reactions) would be reasonable to suppose. This, and other possible functions of the sounds are presently under investigation.

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Electrophoretic Studies on Proteins In the Egg and Hemolymph of the Gypsy Moth With Reference to Isoenzymes

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Abstract: Egg proteins and hemolymph proteins of larval, pupal and adult forms of the gypsy moth (*Lymantria dispar*, Linnaeus) were analyzed electrophoretically. Six isoenzymes: polyphenol oxidase, malic acid dehydrogenase, alcohol dehydrogenase, glucose-6-phosphate dehydrogenase, alpha-glycerophosphate dehydrogenase, and lactic acid dehydrogenase were followed electrophoretically in the metamorphic forms of the gypsy moth. Changes in isoenzyme concentration were observed during development of the insect, and in some cases these differences were sex associated.

INTRODUCTION

The gypsy moth, *Lymantria dispar*, Linnaeus, is the major forest insect of the Northeastern United States. According to U.S. Forest Service estimates, the gypsy moth in a single year is capable of defoliating one and one half million acres of forest shade trees. Its hosts include most species of hardwoods; the oaks, gray birch, and poplar being most highly favored (Baker, 1972).

In efforts to control the population of this pest, studies by the U.S. Dept. of Agriculture dealing with applied and basic research have been in progress. With respect to basic research, a study of the biochemical properties of the blood or hemolymph of the gypsy moth has been a subject of interest in this laboratory. The present study was concerned with the electrophoretic examination of proteins in the diapausing egg, and in the hemolymph of larval, pupal, and adult forms. In addition, some isoenzymes were analyzed electrophoretically throughout the metamorphic stages of the insect.

MATERIALS AND METHODS

Insects. Insects were reared on a modification (ODell and Rollinson, 1966) of a wheat germ diet (Vanderzant et al., 1962) from egg masses collected in the Northeastern United States. Gypsy moth eggs contain a diapausing larva (Lees, 1955) which requires overwintering prior to hatch. A male larva has five instars while the female larva goes through an additional increase in size to form a 6th instar. The female pupa and female adult moth are larger in

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size than the male counterparts. In the laboratory the period from egg to adult lasts about seven weeks.

Samples. In the egg, larval, and pupal stages, pooling of samples was practiced in order to avoid variability in electrophoretic patterns noted in individual insects (Van der Geest and Borgsteede, 1969). Other reasons for pooling or non-pooling of samples, as for adults, are given under the stage described. Larval and pupal samples were obtained from the midpoint of each stage (Magnoler, 1970) in order to be as consistent as possible with respect to the time of development (Greene and Dahlman, 1973).

Egg Fraction. Field collected egg masses had been stored at 4 C for several months during the diapause period (Lees, 1955). Eggs ready to hatch were utilized. The egg masses were dehaired mechanically (Cosenza et al., 1963) and surfaced sterilized (ODell and Rollinson, 1966). To obtain a sample of sufficient protein concentration, 40 eggs were required. Eggs were homogenized in 0.4 ml phosphate buffer (0.01 M, pH 7) and centrifuged at 1600 *g* for 5 minutes to obtain the supernatant which was analyzed.

Larval Hemolymph. Larvae were bled by severing a proleg and hemolymph obtained from members of the same instar was pooled.

Pupal Hemolymph. Pupae were bled by piercing the integument at the junction of the wing and body (Loughton and West, 1965), and pooling was necessary to obtain sufficient volume. To observe whether sex-associated differences were present, hemolymph from male and female forms were obtained separately.

Adult Hemolymph. Adults were decapitated and the hemolymph collected at the exposed neck region (Laufer, 1960). To observe whether sex-associated differences were present, samples from each sex were obtained separately. Pooling of hemolymph was not feasible because of a lack of synchronization in the emergence of the adults. Since adults of certain insects lose blood volume readily (Gere, 1964), and to avoid changes upon storage, individual samples were run as soon as possible after emergence of the adults.

Electrophoresis. Samples of 10 μl were run by anodic polyacrylamide gel electrophoresis (PAGE) (Davis, 1964) with the following modifications: the spacer gel was excluded (Lynsenko, 1972); the system was run at 2.5 ma/tube (Wang and Patton, 1968) at 4 C in precooled buffer. To allow for better current conduction, the quantity of Tris was increased in the running gel from 36.3 g to 48.5 g, and in the sample gel from 5.98 g to 9.6 g (Personal Communication, E-C Apparatus Corp., 3831 Tyrone Blvd., N Street, St. Petersburg, Florida, USA). No melanization of hemolymph was observed if the samples were applied immediately to the gels and electrophoresed.

Proteins. After electrophoresis sample gels were immersed in naphthalene black (1% in 7% acetic acid) for 30 minutes at room temperature. The gels were destained in 7% acetic acid and were stored in this reagent.

Isoenzymes. The isoenzymes analyzed were the following: polyphenol oxidase (PPO), malic acid dehydrogenase (MDH), alcohol dehydrogenase (ADH), alpha glycerophosphate dehydrogenase (α-GPD), glucose-6-phosphate dehydrogenase (G-6-PD), and lactic acid dehydrogenase (LDH). The staining procedures were those of Shaw (1968) with the following exceptions PPO—60 mg of catechol was used as a substrate, in 100 ml of 0.01 M phosphate buffer, pH 6.8. The temperature of incubation for the staining solutions was 37 C. Samples were incubated until bands were fully developed, usually overnight (Grell, 1967). Sample gels were stained for protein in each run and employed as a standard for comparison.

PPO was tested in the egg, each larval instar, male and female pupae, and male and female adults. The remaining five isoenzymes were also determined in the metamorphic stages, except that in the larval stage observations were limited to the 5th instar.

RESULTS

Protein Banding. The patterns obtained for egg proteins and for hemolymph proteins of larval instars, pupae, and adults are shown in Fig. 1. The fastest migrating band was labeled number 1, and the sequence continues back in the direction of the origin (Brewer, 1970). The highest number of consistent bands observed, 13, were found in all stages except the egg fraction which gave a pattern of 8 bands. During development of the insect, bands 11, 7, and 6 showed little or no significant change. Observations noted for the other bands were as follows:

Band 13 was undetected in the egg. In the larval stage it reached its peak concentration in the 4th and 5th instars, and showed a marked decrease in the 6th instar. The band appeared to show no change in concentration in the male pupa, but in the female pupa, it was as concentrated as in the 4th and 5th instars. In the adult the band decreased in the female and was usually non-existent in the male.

In hemolymph of larval instars 1–6, and in the male pupa, one faint band, as shown in Fig. 1, was observed at various times between bands 13 and 12. On other occasions two faint bands were seen in this area.

Band 12 was present in all stages and was very predominant during development. The band increased in concentration from the egg up to the 5th instar, then decreased in the 6th instar. The band concentration showed no change in the pupal stages, but noticeably decreased in the male and female adult. As shown in Fig. 1 a faint band at times was noted between bands 12 and 11, in all stages except in the egg fraction and in hemolymph of larval instars 4 and 5.

Band 10 appeared in the egg fraction and increased in the larval stages with its maximum concentration in the 4th instar. The band decreased in the 5th instar and showed no further change.

Band 9 was present throughout the developmental stages. Its concentration fluctuated in all larval instars, but was significantly increased in the pupal forms. In the adult the band further increased and reached its peak activity in the female.

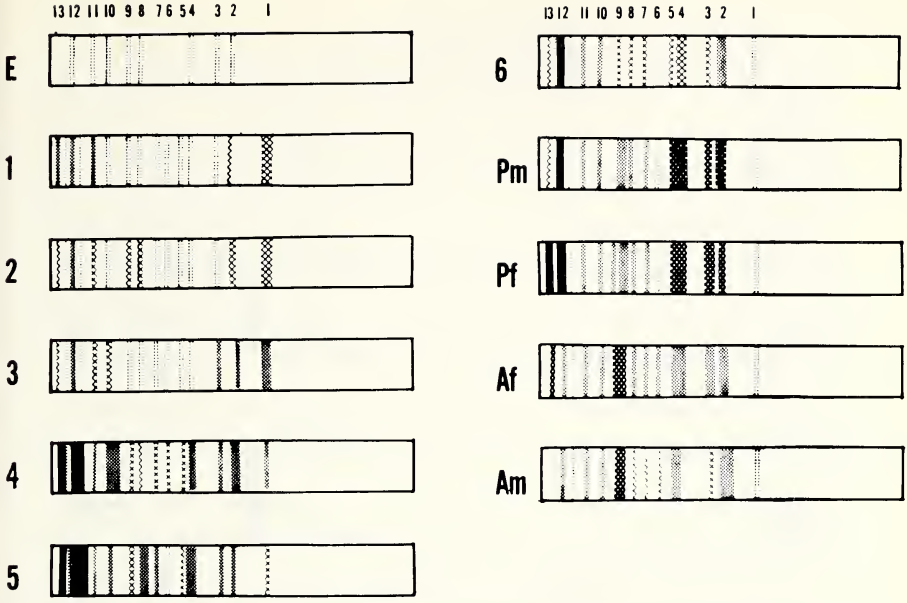

Fig. 1. Anodic Polyacrylamide Gel Electrophoresis (PAGE) of Egg and Hemolymph Proteins of the Gypsy Moth. The origin was at the extreme left of these patterns and those shown in Figs. 2 and 3. E = egg; nos. 1–6 = larval instars 1–6; Pm = male pupa; Pf = female pupa; Af = female adult; Am = male adult.

Band 8 was present in the egg fraction. Its maximum concentration was in the 5th larval instar with a noticeable decrease in the 6th instar. In the pupal forms and in the female adult the band increased slightly over that of the 6th instar, but then decreased in the male adult, equal in concentration to that in the 6th instar.

Band 5 was absent in the egg fraction. It appeared in the larval stages in low concentration. During the pupal and adult stages bands 5 and 4 increased in concentration and formed one band. In the pupal stage the area was much more intense than in the adult stage. The fused band was more concentrated in the male pupa than in the female pupa but was more concentrated in the female adult than in the male adult.

Band 4 appeared in the egg extract. In the larval stages it was fairly constant until the 4th instar where it began to increase up to the 5th instar, then decreased slightly in the 6th instar. In the pupal and adult forms, band 4 was fused with band 5, as described above.
Band 3 was present in the egg stage. It increased in concentration in the 3rd larval instar, remaining constant until it decreased slightly in the 6th instar. The band was increased markedly in the pupal stage over the concentration observed in the larval stages, and greater in the female pupa than in the male pupa. In the adult stage the band decreased and showed less concentration in the male than in the female.

Band 2 appeared in the egg stage. In the larval stage it increased steadily up to the 4th instar. The band increased further again in the pupal stage where it had a greater concentration in the male than in the female. It decreased in the adult stage showing a higher con-

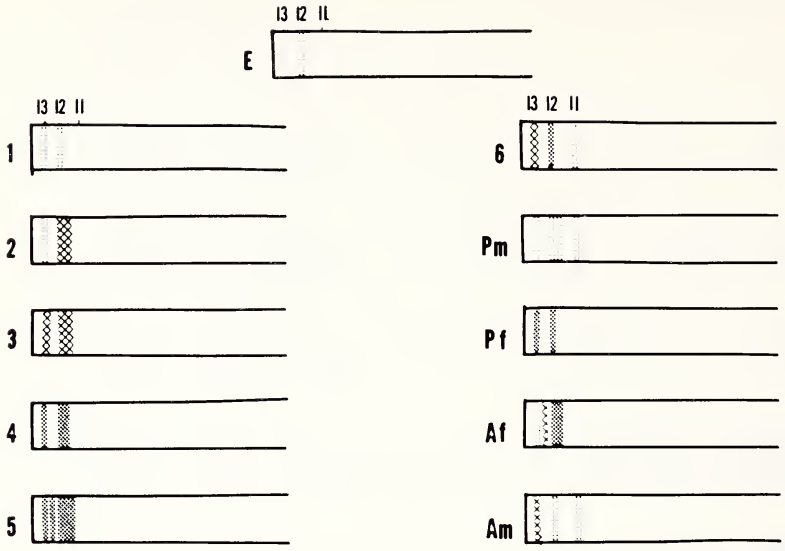

FIG. 2. Anodic PAGE of Polyphenol Oxidase in the Metamorphic Stages of the Gypsy Moth. Refer to Fig. 1 and the text.

centration in the male than in the female. It was noted that after extensive destaining, band 2 appeared to dissociate into 2 bands (not shown in Fig. 1).

Band 1 was absent in the egg. It appeared in the larval stage with maximum concentration in the 3rd instar. The band decreased progressively and remained at a low concentration throughout the rest of development.

Isoenzymes. PPO activity in the metamorphic stages of the gypsy moth was as follows (Fig. 2).

PPO in band 13. PPO was absent in this band in the egg fraction. In larval instars, PPO was present in the early stages, then began increasing at the 3rd instar, leveling off at the 4th and 5th instar, and decreasing in the 6th instar. The female pupa showed an increase in concentration over the 6th instar which was about equal in concentration to that observed for the 4th and 5th instars. There was a decrease in concentration in the male pupa over that noted in the 5th instar. In the adult forms the female decreased in concentration over that for the female pupa, while the male adult appeared to show a slight increase over the concentration noted for the male pupa.

PPO in the area between bands 13 and 12. Activity between bands 13 and 12 was detectable only in the 5th larval instar and the female adult; activity was higher in the 5th larval instar.

PPO in band 12. PPO activity was detectable in the egg fraction. Activity increased in the larval stages up to the 5th instar, and then decreased in the 6th instar. In the pupal stages the female activity was about equal to that of the 6th instar; the activity in the male pupa decreased. The female adult appeared to show a slight increase in activity over the female pupa while the male adult continued to show a decrease in concentration.

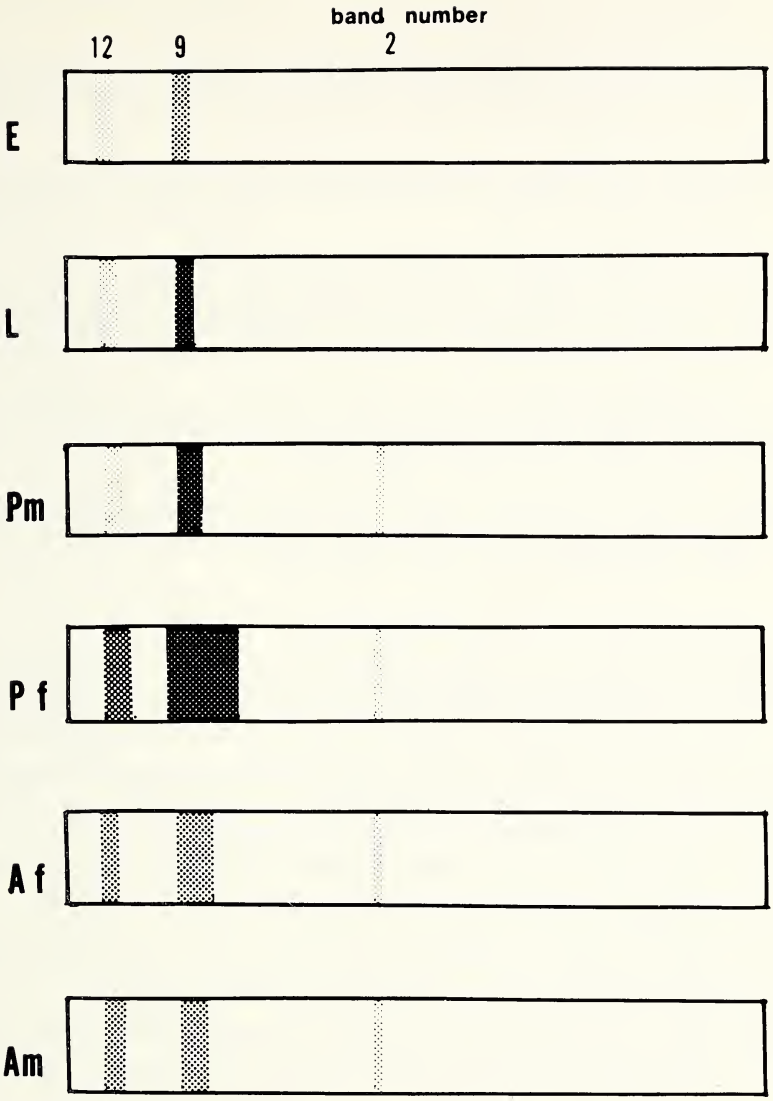

Fig. 3. Anodic PAGE of Malic Acid Dehydrogenase in various stages of the Gypsy Moth. Refer to Fig. 1 and the text. Activity in band 9 in the female pupa also extended into areas of bands 10 and 8.

PPO in band 11. PPO activity was not detected in the egg fraction. In the larval forms the activity was also generally absent in instars 1–5, but at times appeared in instars 3 and 4, (not shown in Fig. 3). The activity was present in the 6th instar but at a low level and was absent or very low (male pupa, male adult) in subsequent stages.

MDH. As shown in Fig. 3 the overall concentration was maximal in the pupal stages. The bands in the female pupa showed greater activity than in the male.

It was observed that ADH, α-GPD, G-6-PD, and LDH were all detected in samples of the egg fraction. However, in later stages, variabilities were noted in band number and intensity, and activity was expressed in terms of total staining of the bands. Additional observations were as follows:

ADH. The activity was maximal in the 5th larval instar, then decreased in succeeding stages with no significant differences noted between the male and female of the pupal and adult stages. Major bands were 12 and 11.

α-GPD. Activity was maximal in the 5th larval instar, decreased slightly in the pupal stage, and increased again in the adult stage, approximating the level of the 5th larval instar. There appeared to be no significant difference in activity between the sexes in the pupal and adult forms. A major band corresponding to protein bands 7, 6 and 5 (7–5) was observed.

G-6-PD was maximal in the 5th larval instar, then decreased with the remainder of insect development. The bands in the female pupa and female adult were slightly more concentrated in the male forms. Band 10 was a major band.

LDH was maximal in the 5th larval instar, decreasing in the pupal stage and further in the adult. There seemed to be no marked differences in intensity between the sexes in either the pupal or adult stage. Bands 13 and 12 were major bands.

DISCUSSION

Characteristic bands have been reported in electrophoretic patterns from insects. Van der Geest and Borgsteede (1969) noted an increase in concentration of "slow moving fractions" toward the end of larval life in *Pieris brassicae,* and a decrease in these "high molecular weight proteins" during the pupal stage. Hudson (1966) referred to a "common" blood protein, band 11, in the larval stage of the tomato hornworm. She believed it was similar to: (a) the main fraction in the hemolymph of *Galleria mellonella* (Denuce, 1958); (b) band 1 in the hemolymph of *cecropia* and *cynthia* larvae (Laufer, 1960); (c) the "common protein" noted by Whittaker and West (1962) in hemolymph from 18 insects; and (d) band 6 in the hemolymph and tissue of *Malacosoma americanum* and *Rothschildia orizaba* (Loughton and West, 1965).

Observations in the anodic PAGE system for gypsy moth center on predominant bands during the following stages: *larva*—13, 12; *pupa*—13 (female), 12, 9, 5–4 (combined), 3, 2; *adult*—9, 5–4 combined, 3 (female), 2.

Enzymes have been followed in various stages of insect development (Laufer, 1961; Chen and Levenbook, 1966; Knowles and Fristrom, 1967; Wright and Shaw, 1969).

PPO was maximal in the hemolymph of the 5th instar (Fig. 2). In insects PPO, in addition to its role in the tanning and hardening of the cuticle (Brunet, 1965), may be implicated in a defense function against invading microorganisms and parasites (Taylor, 1969).

ADH, LDH, and G-6-PD were maximal in hemolymph of the 5th instar,

decreasing proportionately in later stages. α-GPD did not show a general decrease in concentration in later stages from a maximal level in hemolymph of the 5th instar. The enzyme decreased slightly in the pupal stage but then increased in the adult, approximating the concentration in the 5th instar.

Unlike the other isoenzymes followed in the development of the gypsy moth, MDH was maximal in the female pupa (Fig. 3). The reduced activity in hemolymph of the male pupa was approximately equal to that observed in the hemolymph of the 5th instar.

In studies on the flight muscle of the African locust (*Locusta migratoria*), Bücher (1965) reported involvement of MDH, LDH, α-GPD, and G-6-PD. α-GPD has also been implicated in diapause metabolism (Gilmour, 1965).

Sex related differences have been cited in the literature with respect to electrophoretic patterns of insect material. Some investigators believed that these differences were in terms of protein levels (Stephen and Steinhauer, 1957; Hudson, 1966). By this parameter the present study demonstrated sex-associated differences for certain protein bands. *Band 13* was reduced in the male pupa in comparison to the female pupa. *Band 13*, present in low concentration in the female adult, was absent in the male adult. In the adult, *Bands 9 and 8* were more concentrated in the female. *Bands 5–4* (combined) were slightly higher in the male pupa, in comparison to the female pupa, but in the adult forms, the reverse was true. In the pupae, *Band 3* was slightly higher in the female, and in the adult forms, significantly higher in the female. *Band 2* was slightly higher in the male pupa and male adult in comparison to the female of these stages.

Sex-associated differences observed for the isoenzymes followed in the development of the gypsy moth were as follows: *PPO* was greater in hemolymph of the female pupa and female adult than in the male of these stages (Fig. 2). *MDH* was significantly higher in hemolymph of the female pupa in comparison to the male, and slightly higher in the female adult in comparison to the male (Fig. 3). G-6-PD was observed to be slightly more concentrated in hemolymph of the female pupa and female adult than in the male of these stages.

A 6th larval instar occurs in the female of the gypsy moth. Although protein banding and isoenzyme analyses did not reveal any unusual observations, undoubtedly, this stage of development would demonstrate important changes in other compounds, such as hormones.

The egg of the gypsy moth contains a diapausing larva, and very likely hemolymph proteins are present at this stage. The egg extract was analyzed not necessarily for unique proteins, but to demonstrate the presence of isoenzymes in insect eggs (Agrell, 1964).

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Comparative Properties of Hemolymph of the Gypsy Moth and the European Pine Sawfly

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Abstract: A number of properties of hemolymph were determined on two major forest pest insects: the gypsy moth and the European pine sawfly. The parameters measured include: pH, visible absorption spectra, sedimentation coefficients, electrophoretic patterns of proteins, lipids, carbohydrates, and isoenzymes, and amino acid analyses.

INTRODUCTION

The gypsy moth (*Lymantria dispar* Linnaeus), a lepidopteran, and the European pine sawfly (*Neodiprion sertifer* Geoffroy), a hymenopteran, are insect pests which annually cause extensive damage to trees. In the United States an active research program by the Department of Agriculture has been in progress on establishing suitable control measures for these insects.

Our knowledge of the biochemistry and physiology of the gypsy moth and the European pine sawfly is lacking, and in this regard the literature does not contain sufficient data on the properties of the hemolymph of either insect. The present study was concerned with resolving some of these deficiencies while providing a comparative analysis on the hemolymph of each insect.

MATERIALS AND METHODS

Insects. The gypsy moth and the European pine sawfly were obtained from local regions. Larvae of the gypsy moth were reared from egg masses on a synthetic diet (Vanderzant et al., 1962, ODell and Rollinson, 1966). Larvae of the European pine sawfly were collected from its hosts, Scotch pine and red pine. To offer a comparison of the properties of hemolymph on an approximate size basis, the 4th larval stage of the gypsy moth and the final larval stage of the European pine sawfly were used.

Hemolymph. Blood of either insect was obtained by pricking a proleg of a sufficient number of individuals and pooled without regard to sex. With time the blood of the gypsy moth melanizes when exposed to air. To inhibit the reaction a small crystal of phenylthiourea was added to gypsy moth blood in

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certain experiments. Blood of the European pine sawfly does not melanize when exposed to air.

pH. Values were obtained with a Corning Model 12 pH meter, using a microelectrode.

Visible Absorption Spectra. A Hitachi, Perkin-Elmer, Model 139 spectrophotometer was used. Blanks were standard phosphate buffers corresponding in pH to that of the blood of the insect measured.

Sedimentation Coefficient. Blood of the gypsy moth containing a small crystal of phenylthiourea or blood of the European pine sawfly were diluted with buffer (Miller and Golder, 1950). Sedimenting peaks were measured from Schlieren patterns obtained with a Model E analytical ultracentrifuge (Beckman Co.). The values obtained were corrected to standard conditions, $S_{20,w}$ (Schachman, 1959).

Polyacrylamide Gel Electrophoresis. Samples containing 10 μl of blood were electrophoresed anodically in 7.5% polyacrylamide gels (Davis, 1964), omitting the spacer gel (Lysenko, 1972). The system was run at 2.5 ma/tube (Wang and Patton, 1968) at 4°C in precooled (Hudson, 1966) buffer for 50 minutes. To allow for better current condition, the quantity of tris was increased in the running gel from 36.3 to 48.5 g, and in the sample gel from 5.98 to 9.6 g (Personal communication, E-C Apparatus Corp., 3831 Tyrone Blvd., N. Street, St. Petersburg, Florida). *Proteins* were stained in naphthalene black (lg/100 ml of 7% acetic acid) for 30 minutes, and destained with 7% acetic acid. Corresponding unstained gels were analyzed for lipoproteins, glycoproteins, and isoenzymes. *Lipoproteins* were stained for 24 hours in 100 ml of an aqueous solution containing 0.55 g sudan black, 7.5 ml acetic acid, and 70 ml ethanol. Destaining was accomplished through 2–3 changes of 7.5% acetic acid at room temperature. *Glycoproteins* were demonstrated by first fixing the gel samples in 7.5% acetic acid at room temperature for 1 hour, and then immersing the gels in 0.2% aqueous periodic acid, followed by refrigeration for 45 minutes. The gels were then set in a trough containing Schiff reagent and again refrigerated for 45 minutes. Destaining was accomplished in 2–3 rinses with 10% acetic acid at room temperature. *Isoenzymes* were determined using the staining procedures of Shaw (1965) with the following exceptions: peroxidase-Brewer's procedure (1970) was used; polyphenol oxidase—60 mg of catechol in 100 ml 0.01 M phosphate buffer, pH 6.8 was employed (Brown and Mazzone in preparation). The temperature of incubation for the staining procedures was 37°C except for esterase and peroxidase, which were incubated at room temperature.

Amino Acid Analysis. The blood of either insect was immediately freeze-dried and melanization did not occur. Blood was deproteinized with 1% picric acid

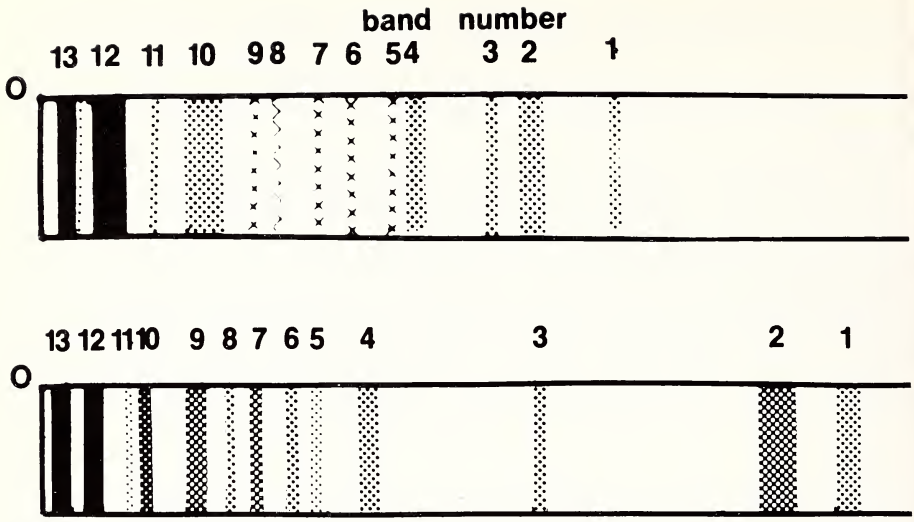

FIG. 1. Anodic polyacrylamide gel electrophoresis of hemolymph proteins. Top: 4th larval instar of the gypsy moth; Bottom: final larval instar of the European pine sawfly. O = origin. Refer to text.

and the supernatant passed through a Dowex 2-X8 resin (200–400 mesh, chloride form) to remove the picric acid. The effluent was evaporated to dryness and the residue analyzed with a Beckman Model 121 Automatic Analyzer (Stein and Moore, 1954; DeWolfe et al., 1967).

RESULTS

Color, pH, Visible Absorption Spectra, and Sedimentation Studies. Larval hemolymph of the gypsy moth had a blue-green color with an absorption maximum at 663 nm and a minimum at 520 nm. The pH of the blood was 6.57. Two sedimenting peaks were observed: a 17.6S major peak, which was 76% of the sedimenting material and a slower, 7.7S peak, representing 24% of the sedimenting material. Larval hemolymph of the European pine sawfly had a yellow color but did not exhibit a true spectral curve. Absorption decreased progressively from 400 nm to 800 nm. The pH of sawfly blood was 6.99 and one sedimenting peak with a value of 17.5S was observed.

Polyacrylamide Gel Electrophoresis. The protein patterns obtained are shown in Fig. 1. For each insect blood 13 bands were present, although occupying different sites along the gel. In each case, bands 13 and 12, the slowest migrating bands were predominant.

Lipids and Carbohydrates. In gypsy moth hemolymph lipids were detected in areas along the gel corresponding to protein bands 13 and 12, and in sawfly

Table 1. Isoenzymes in hemolymph of the gypsy moth (gm) and the European pine sawfly (Eps). The numbers refer to the corresponding protein bands as shown in Fig. 1. Italicized bands indicate areas of major enzymatic activity.

Isoenzyme	Corresponding Protein Band	
	gm	Eps
Adenylate Kinase	13,*12*,6,*4*,1	13,10,*3*
Esterase	13,*12*	13,*12*,10
Galactose-6-Phosphate Dehydrogenase	12,10,*7*,4,*2*	13,*10*,3
Fumarase	*13*,*12*,11,10,9–8,7,6,5,4,*3*,*2*,1	13,*10*,3
Hexokinase	13,12,10,8–6,5–4,*2*,1	*13*,10,5,4,*3*
Phosphoglucomutase	13,12,10,8–6,5–4,*2*,1	13,11,*10*,3
Xanthine Dehydrogenase	*13*,*12*,11–10,8–7,3,*1*	*13*,10,3
Peroxidase	12	13,12
Galactose Dehydrogenase	*13*,*12*,11,10,8,7,6,*4*,1	13,12,*10*,8,5,4
Polyphenol Oxidase	*13*,*12*,11	*13*,*12*,10
Malic Acid Dehydrogenase	12,*10*,9,8,2	*13*,*12*,10,*9*,4
Lactic Acid Dehydrogenase	*13*,*12*,11,10,9,7–6,*3*,*2*,1	13,*12*,*10*,8,7,5,*4*
alpha-Glycerophosphate Dehydrogenase	12,11,10,9,8,*7–5*,4,3,2,1	13,*12*,*10*,8,7,5,*4*
Alcohol Dehydrogenase	*12*,*11*,10–9,7–6,4,3,2,1	13,12,11,10,8,7,5,*4*
Creatine Kinase	*13*,*12*,9,8,7,6,5,4,*1*	
Glutamic Dehydrogenase	13,12,11,10,8–5,3,2,1	
Glucose-6-Phosphate Dehydrogenase	12,*10*,8–7,6–5,3,2	

hemolymph, bands 13 and 10. Carbohydrates were detected in areas along the gel in all bands for the gypsy moth except 6 and 1, and were present in bands 13, 12, 10, 8 and 3 of sawfly blood.

Isoenzymes. The isoenzymes present in the protein bands of each insect blood pattern are given in Table I. In gypsy moth blood 17 isoenzymes were observed, while in blood of the European pine sawfly, 14 isoenzymes were present.

Amino Acid Analysis. Table II presents the number and concentration of amino acids present. For gypsy moth blood, glutamine and lysine were present in the highest amount for the common amino acids. Tryptophane and hydroxyproline were absent. Urea, which was also measured in the amino acid analyses was present in relatively high concentration in the gypsy moth blood sample. In sawfly blood glutamine and asparagine were present in the highest amount for the more common amino acids, while sarcosine was present in the highest amount of all compounds measured. Aspartic acid was absent in sawfly blood.

DISCUSSION

The blue-green pigment of larval hemolymph of lepidoptera is believed to be a bile pigment (see Schmidt and Young, 1971) and possibly a mesobiliverdin (Van Der Geest, 1968). Larval hemolymph of the sawfly, although yellow in

TABLE 2. Amino acids and related compounds in hemolymph[a] of the gypsy moth (gm) and the European pine sawfly (Eps). a = μmoles of amino acid/compound in 10 mg of freeze dried blood; ND = not detected.

Amino Acid/Compound	gm	Eps	Amino Acid/Compound	gm	Eps
Tryptophane	ND	0.35	Aminoadipic Acid	ND	1.04
Lysine	2.88	1.28	Proline	1.44	1.44
Histidine	2.48	1.72	Glycine	0.44	2.12
Ammonia	0.40	0.84	Alanine	0.72	2.12
Arginine	0.80	0.49	Citrulline	ND	ND
Phosphoserine	0.04	0.08	Aminobutyric	ND	ND
Taurine	ND	0.16	Valine	0.72	0.28
Phosphoethanolamine	1.44	1.80	Half-Cystine	0.04	0.04
Urea	6.44	0.68	Cystathionine	0.56	0.20
Aspartic Acid	0.04	ND	Methionine	0.44	0.12
Hydroxyproline	ND	0.04	Isoleucine	1.84	0.24
Threonine	0.52	0.88	Leucine	0.36	0.20
Serine	0.72	1.44	Tyrosine	0.24	0.40
Asparagine	1.48	2.64	Phenylalanine	0.24	0.04
Glutamic Acid	0.17	0.11	B-Alanine	ND	0.92
Glutamine	4.80	3.90	Aminoisobutyric Acid	ND	ND
Sarcosine	ND	9.93			

color, did not exhibit a true spectral curve. Possibly there are interfering substances present which mask the true absorption of the prosthetic groups, which for yellow chromoproteins are believed to be B-carotene and lutein (Van Der Geest, 1968; Hackman, 1952). Studies on the characterization of the hemolymph pigments for these two insects will be reported in a subsequent study (H. M. Mazzone and S. E. Brown).

Heimpel (1961) found the pH of hemolymph of a number of insects to range from 6.2 to 7. For the gypsy moth a value of 6.75 for the last instar hemolymph was observed, compared to our value of 6.5 for hemolymph of the 4th instar. He observed a value of 6.81 for hemolymph of the last instar of the European pine sawfly compared to our value of 6.99 at the same instar.

A common sedimentation value of approximately 17S was observed for the fastest sedimenting peak in hemolymph of the gypsy moth and for the single component of the hemolymph of the European sawfly. Lauffer (1943) observed a main component in hemolymph of Bombyx mori having a value of 16S.

In the present study, protein electrophoretic patterns showed two predominant bands near the origin. The possibility of a "common" protein in insects has been suggested by Whittaker and West (1962) in their electrophoretic studies on 18 species of insects. In hemolymph protein patterns, which included a sample from the European pine sawfly, they observed a predominant band close to the origin in all cases. Hudson (1966) also referred to a "common" protein in hemolymph of *Protoparce quinquemaculata* and believed it to be

similar to a particular hemolymph protein in electrophoretic patterns obtained for *Hyalophora cecropia* and *Samia cynthia* (Laufer, 1960); *Malacosoma americanum* (Whittaker and West, 1962); and *M. americanum* and *Rotschildia orizaba* (Loughton and West, 1965). In these studies no sedimentation values were obtained for hemolymph proteins which might have supported the concept of common proteins in insects.

Lipoproteins and glycoproteins were observed in hemolymph of each insect reported in the present study. Indeed, carbohydrates were associated with all the protein bands of gypsy moth hemolymph, except bands 6 and 1. Bennett et al. (1968) reported lipids and carbohydrates in association with the main hemolymph protein of the japanese beetle, *Popilia japonica*. Siakatos (1960 a,b) suggested that the blood proteins serve as carriers of nutrients such as lipids and carbohydrates.

Creatine kinase, glutamic dehydrogenase and glucose-6-phosphate dehydrogenase were present in larval hemolymph of the gypsy moth but were absent in the European pine sawfly. A detailed study of isoenzymes in the metamorphic stages of the gypsy moth is under study (S. E. Brown and H. M. Mazzone). Isoenzymes in insects have been assigned various functions, e.g., PPO is involved in the tanning and hardening of the cuticle (Brunet, 1965) and in defense mechanisms (Taylor, 1969).

Amino acids in high concentrations of the gypsy moth were glutamine, lysine, histidine, isoleucine, and proline. Tryptophane, hydroxyproline, and sarcosine were absent. A detailed study of the amino acids in the metamorphic stages of this insect is in progress (R. T. Zerillo) and a high concentration of urea in hemolymph has been noted.

In hemolymph of the European pine sawfly sarcosine was present in the highest amount followed by glutamine, glycine, and alanine. Aspartic acid was absent.

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Adults and Larvae of a New Species of *Gelis* (Hymenoptera, Ichneumonidae) Parasitizing Eggs of *Schizocosa saltatrix* (Araneida, Lycosidae)

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Abstract: Adults and cephalic structures of the final instar of a new species of *Gelis* from eastern Canada are described. The adults and the cocoon from which each had emerged were found in the egg sac of the spider *Schizocosa saltatrix* (Hentz.). The cephalic structures were extracted from the cocoons. Adults and final instars are compared with those of other species of *Gelis*.

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Adults and larval remains of a new species of *Gelis* were extracted from the egg sac of a female spider, *Schizocosa saltatrix* (Hentz.). The egg sac contained seven adult females and the seven cocoons from which they had emerged. The cephalic structures of the larvae were found inside the cocoons. The larvae had eaten all of the eggs. The egg sac was attached to the spinnerets of the spider. The spider was recovered from a pitfall trap in undisturbed (except by fire) tall-grass prairie at Windsor, Ontario. Females carry the egg sac, containing at least 50 eggs, and also, for a time, the young on hatching.

The genus *Gelis* Thunberg is a large one containing many species, mostly occurring in the Holarctic region. The hosts of the group are varied but usually consist of insects that make cocoons or small cases of silk-like material. Known hosts include cocoons of Chrysopidae and various small Lepidoptera, Ichneumonidae, Braconidae, larval cases of Psychidae and Coleophoridae, and egg sacs of spiders. The Nearctic species of *Gelis* have not been reviewed since Strickland's (1912) treatment of the group. The species occurring in Finland were recently revised by Hellén (1970). The head capsule of the final instar of *Gelis tantillus* (Cresson) was described and figured by Short (1959), of *urbanus* (Brues) by Finlayson (1960), of *tenellus* (Say) by Finlayson (1962). The head capsule of *Gelis fasciatus* (Fabricius) was figured by Beirne (1941), of *tenellus* by Clancy (1946), and that of an unknown species of *Gelis* was figured by Guppy and Miller (1970). The head capsule of *Gelis bruesii* (Strickland) was described by Short (1959).

Gelis **schizocosae** n. sp.

Adult. Female body (Fig. 1) moderately stout, length 3.6–3.9 mm. Head (Figs. 2–4) moderately stout, maximum head width two times mesoscutum width between spiracles. Face (Fig. 2) with prominent, broad, median bulge. Clypeus (Fig. 2) strongly convex, not sharply delimited from face, apical margin sharp, reflexed, slightly arcuate, without median projections. Temple (Figs. 3, 4) relatively long, length 0.2 mm; length of temple to width of eye in ratio 2:3. Antenna (Fig. 5) relatively short, length 1.5–1.6 mm, with 14 to 16 flagellar articles, with first flagellar article (postannellus) longer than second, three times

Plate 1. FIGS. 1–6. 1, habitus, lateral aspect; 2, head, frontal aspect; 3, dorsal aspect; 4, laterodorsal aspect; 5, antenna; 6, ovipositor, lateral aspect.

longer than wide; flagellar articles 1 to 4 each 0.07 mm wide, each succeedingly shorter in length.

Thorax (Figs. 7, 8) with pronotum very broad in dorsal aspect, with very narrow, deep impression separating collar from remainder of pronotum, the latter with a submarginal transverse swelling immediately in front of pronotal sulcus; pronotum medially in same plane as anterior portion of mesoscutum. Mesoscutum not much shorter than propodeum, in ratio 4:5, dorsally at middle broadly flattened, appearing subquadrate; notauli not defined. Scutellum only vaguely discernible. Mesopleurum at upper posterior corner with impression prominent; sternaulus not defined. Propodeum short, length 0.4 mm, strongly declivous from just behind middle, with apical transverse carina only and this indistinct medially and laterally except at apices. Front tibial spur less than half length of front basitarsus, middle tibial spur about half length of middle basitarsus. Wings absent.

First abdominal segment (Fig. 9) relatively elongate, length from spiracle to apex 0.2 mm; first tergite increasingly broader apically, much broader from apical third; with apical

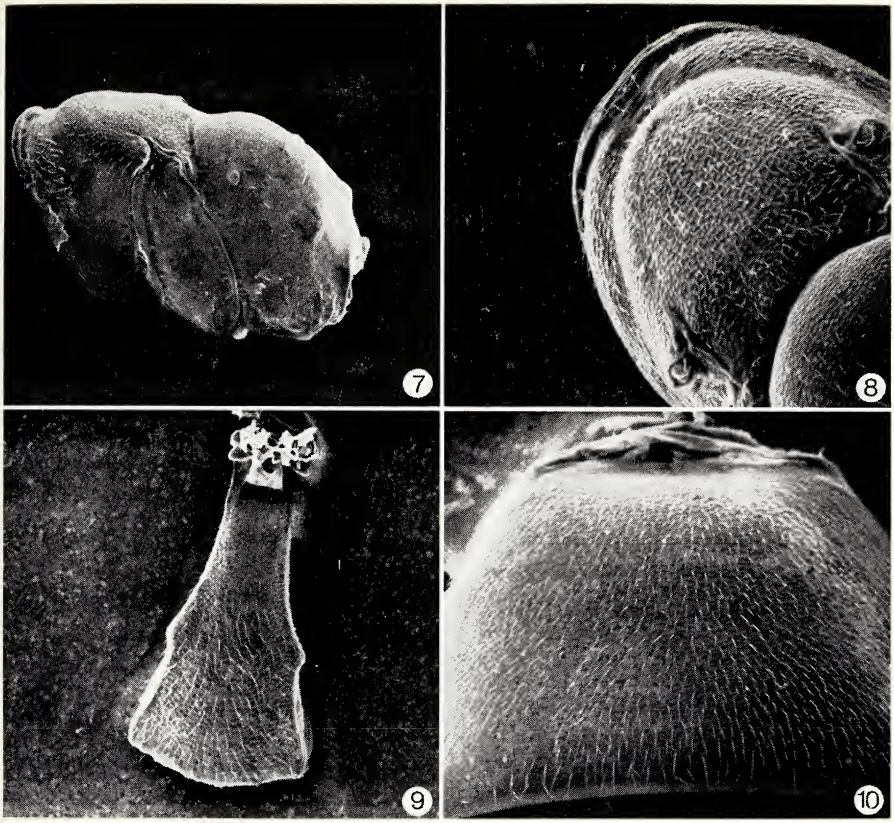

Plate 2. Figs. 7–10. 7, thorax, laterodorsal aspect; 8, pronotum, laterodorsal aspect; 9, first abdominal tergite, dorsal aspect; 10, second abdominal tergite, dorsal aspect.

margin slightly arcuate; spiracles distinct but not prominent. Ovipositor (Fig. 6) with sheaths short, length 0.6–0.7 mm, about same length as first abdominal segment.

Body with evenly distributed, minute sculpture, subopaque; distinctly pubescent, with setae evenly spaced (Fig. 8). Abdominal tergites with setae shorter and more dense, each separated in distance by its own length from adjacent seta (Fig. 10).

Body colour black and ferrugineous, the ferrugineous colouration relatively pale and with a slight fulvous tinge. Head ferrugineous and black. Face, clypeus, mandibles, and antennal scape ferrugineous; frons dark ferrugineous; temple, vertex, and cheeks black; temporal orbit at middle proximal to eye with ferrugineous maculation; antenna with first flagellar ferrugineous, apical articles fusco-ferrugineous. Thorax ferrugineous, propodeum slightly darker. Legs ferrugineous; middle femora each on dorsal surface and at apical third, middle tibiae each on dorsal surface and at basal and apical third tinged fuscous. Hind legs ferrugineous, femora each in apical half, tibiae each in apical and basal third tinged fuscous. Abdomen black and ferrugineous, the ferrugineous colouration slightly darker than that of head and thorax; first tergite ferrugineous, second black in basal third, apically ferrugineous, third to fifth black, apical tergites ferrugineous, at sides slightly tinged fuscous.

TABLE 1. Comparative characteristics of females of **schizocosae** n. sp. and *canadensis*.

Species	*schizocosae*	*canadensis*
Character (in mm)		
Total length	3.60–3.90	2.60–3.10
Head—greatest width	0.77–0.85	0.65–0.75
Temple—length	0.20–0.22	0.12–0.15
Eye—greatest width	0.32–0.35	0.30–0.35
Antenna—length	1.55–1.65	1.47
Antennal flagellar I—length	0.17–0.20	0.12–0.17
Propodeum		
—length	0.42–0.45	0.47–0.50
—width	0.32–0.35	0.35–0.37
Mesoscutum		
—length	0.35–0.37	0.25–0.37
—width between spiracles	0.32–0.35	0.35–0.37
Front leg		
—tibial spur length	0.12–0.17	0.12
—basitarsus length	0.25–0.27	0.27
Middle leg		
—tibial spur length	0.12–0.15	0.12
—basitarsus length	0.22–0.25	0.30
First tergite—length spiracle to apex	0.22–0.25	0.17–0.20
Ovipositor sheath—length	0.62–0.70	0.53

Remarks. Males are not known. The females are similar to females of *canadensis* Cresson, yet exhibit many differences as well. Some of the more significant comparative characteristics of the species of *Gelis* are the degree of delimitation of the clypeus from the face, the length of the flagellar articles in relation to the width, the shape of the pronotum, the length of the mesoscutum and propodeum and the relation between the two, the amount of reduction in carination of the propodeum, the degree of declivity of the propodeum posteriorly, and the length of the ovipositor. Comparative quantitative data are given for individuals of **schizocosae** n. sp. and *canadensis* in Table I. There are significant differences in measurements of the head, flagellar articles, propodeum, and mesoscutum between the two species. The clypeus is not sharply delimited from the face in either species and the flagellar articles are short relative to the width whereas those of many Nearctic species are elongate. The temple is distinctively longer in **schizocosae** n. sp. females. The pronotum is markedly different in *canadensis* females, at a much lower plane relative to the mesoscutum than that of **schizocosae** n. sp. females and the collar is strongly narrowed. The front and middle tibial spurs are distinctly longer in **schizocosae** n. sp. in proportion to length of the basitarsus than in *canadensis*. The proportional lengths and widths of the head, mesoscutum, and propodeum are somewhat similar, though not the same (Table I), and the amount of declivity of the propodeum posteriorly is similar. The ovipositor sheaths of females of both species are short compared to many other species of *Gelis*. The body of **schizocosae** n. sp. and *canadensis* females is minutely sculptured, subopaque, and without evident punctation. The head and most of the abdominal tergites are darker than the rest of the body in females of both species.

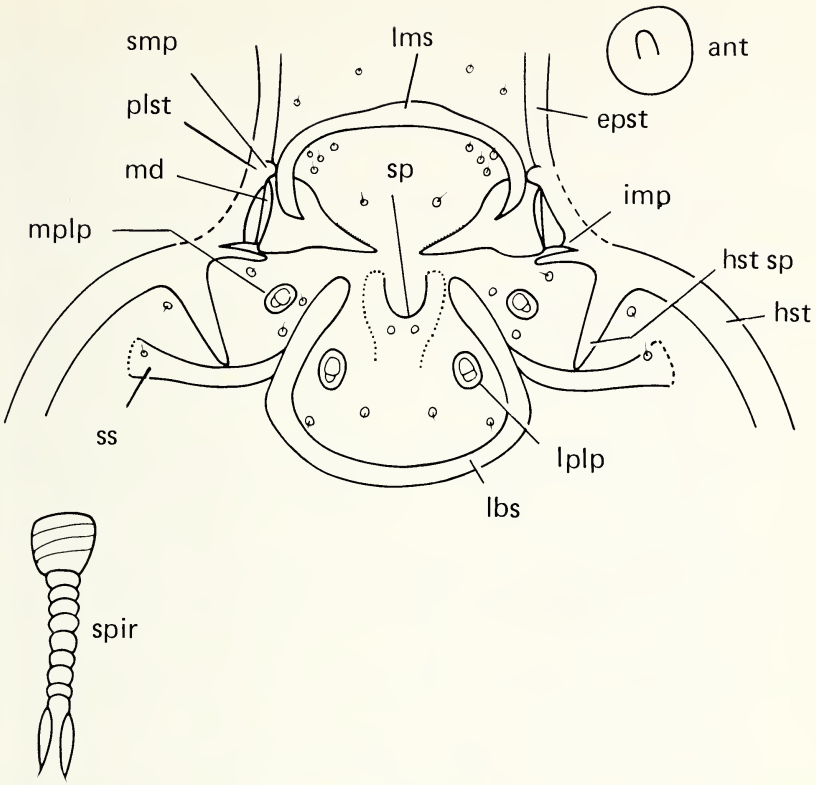

Plate 3. Fig. 11. Cephalic structures of final instar; ant, antenna; epst, epistoma; hst, hypostoma; hst sp, hypostomal spur; imp, inferior mandibular process; lbs, labial sclerite; lms, labral sclerite; lplp, labial palp; md, mandible; mplp, maxillary palp; plst, pleurostoma; smp, superior mandibular process; sp, silk press; spir, spiracle; ss, stipital sclerite.

Type material. Holotype, adult female, Windsor, Ontario, collected July, 1976, J. H. Redner. Host: *Schizocosa saltatrix* (Hentz). Type number 15203, Canadian National Collection, Ottawa.

Paratypes. Six adult females, same locality and host data as holotype, deposited in Canadian National Collection, Ottawa. Head capsules of two larvae mounted on slides and associated with adults, other five in cocoons in microvial under one of the adult females, all from the same host.

Larva. Cephalic structure of final instar (Fig. 11) moderately sclerotized. Epistoma lightly sclerotized, slender, incomplete dorsally. Superior mandibular processes well developed. Pleurostoma lightly sclerotized, more lightly than hypostoma. Inferior mandibular processes each with two struts. Hypostoma relatively long, not abruptly curving lateroventrally. Hypostomal spur three times as long as width at base. Stipital sclerites each lightly sclerotized distally, meeting labial sclerite at ventral third of lateral arm, not nearly reaching hypostoma. Labial sclerite subtriangular in shape, lateral arms straight, only slightly thickened dorsally, each meeting ventral part at obtuse angle. Prelabial sclerite absent. Maxillary and labial palpi each slightly bulbous, with two sensilla, dorsal sensillum larger

than ventral. Silk press U-shaped, sclerotized; area ventral to silk press lightly sclerotized, sclerotized more lightly than silk press; two small sensilla beneath external opening of press. Mandibles small, each with straight blade, with one row of very fine, small, numerous teeth on dorsal surface, evenly spaced, and extending from near base to near apex, ventral surface without teeth. Labral sclerite rounded, not extending strongly dorsally, bending sharply medially at each end, extending to dorsal third of mandible. Antennae papilliform, each 2.2 times as long as width at base. Spiracle (Fig. 11) with four reticulations on atrium, with long stalk of eight or nine annulations and closing apparatus, the latter distant from atrium. Integument densely covered with cone-shaped protuberances, with some short setae.

Remarks. The mandible of larvae of **schizocosae** n. sp. (Fig. 11) is unique among the described cephalic structures of Nearctic species. There is one row of small teeth on the dorsal surface and there are no teeth on the ventral surface. This characteristic of the mandible is shared by *Dichrogaster* (= *Otacustes*) as defined by Short (1959). There are two rows of teeth on the dorsal surface of the mandible of larvae of *Gelis urbanus* and *tenellus*, and there are teeth on both the dorsal and ventral surfaces of the mandible of larvae of *tantillus*, *bruesii*, and *fasciatus*. Larvae of **schizocosae** n. sp. share an incomplete epistoma with those of *urbanus*, *tantillus*, *bruesii*, and *fasciatus*. The epistoma of specimens of *tenellus* is complete. The hypostomal arm of **schizocosae** n. sp. individuals is longer than that of specimens of *urbanus* and *tenellus* and does not curve abruptly ventrally, but also is not straight as in *tantillus*. The hypostomal spur is three times as long as the width at base instead of four times as in *urbanus*, *tenellus*, and *tantillus*. The dorsal arms of the labial sclerite are slightly thickened dorsally as in *tenellus*. The stipital sclerite meets each arm of the labial sclerite in the ventral third as in *tenellus* and *tantillus*. The area ventral to the silk press is more extensively sclerotized and is not divided in **schizocosae** n. sp. The labral sclerite is widely arched and extends well down over the mandibles ventrally and turns medially at each end as in *tenellus* and is not extended dorsally as in *urbanus*.

The knowledge of larvae of *Gelis* is still at too early a stage and the number of species so far described is too limited to allow postulations on relationships. Also, a comparative study of the many species is needed.

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A FURTHER LOOK AT THE GENUS *PROROPS* (HYMENOPTERA, BETHYLIDAE)

Howard E. Evans

Abstract.—*Prorops* Waterston, formerly regarded as a monotypic genus, is now known to contain three species, of which the following two are new: *petila* (Louisiana and Brazil) and *obsolet*a (Trinidad). *P. nasuta* Waterston, the type-species, is now recorded for the first time from Jamaica, Cuba, and California.

The genus *Prorops* was described by Waterston in 1923 to include a single African species, *nasuta* Waterston. Shortly thereafter this species was introduced into Brazil for biological control of the coffee berry-borer, *Stephanoderes hampei* Ferr. (Scolytidae) (Hempel, 1934). When I reviewed the American genera of Bethylidae in 1964, I was familiar only with the one species, *nasuta*, and had seen specimens only from Africa and from eastern Brazil. I have since seen specimens from the West Indies and also from southern California, suggesting that the species is now widespread in warmer parts of the Americas. I have also discovered two additional species of *Prorops*, described below. Presumably these are native American species, although it is possible that they have been distributed widely through commerce, like a number of other Bethylidae. One of these species is believed to attack Scolytidae, like *nasuta*. Both of the new species have the general features of *nasuta*, although the frontal process is not bifid as in that species. One of them has the radius of the fore wing entirely absent, in this respect falling especially closely to the related genus *Cephalonomia*. For a review of generic characters, see Waterston (1923) and Evans (1964).

Key to Species

1. Head not or but slightly longer than wide (width 0.8–1.0 × median length in ♀, about 1.0 in ♂); frontal process bifid (Fig. 1); radius of fore wing subequal to or slightly longer than distance from wing base to stigma (Fig. 4) *nasuta* Waterston
– Head long, its sides subparallel (width 0.60–0.74 × median length in ♀, 0.79–0.85 × median length in ♂); frontal process blunt or somewhat trifid (Figs. 2, 3); wings very slender, radius either absent or longer than above (Figs. 5, 6) 2
2. Radius present, about 1.4 × as long as distance from wing base to stigma (Fig. 5); notauli absent; head very long, width 0.60–0.65 × length in ♀, 0.78 × length in ♂ (Fig. 2) *petila*, n. sp.

– Radius completely absent (Fig. 6); notauli present as linear streaks; head less elongate, width 0.72–0.74 × length in ♀, 0.85 × length in ♂ (Fig. 3) *obsoleta*, n. sp.

Prorops petila, n. sp.
(Figs. 2, 5)

Holotype.—♀, LOUISIANA: Jena, 23 Oct. 1967 (L. S. Pickard), Loblolly pine, reared with *Dendroctonus frontalis* (Zimm.).

Allotype.—♂, same data [both U.S. Nat. Mus.].

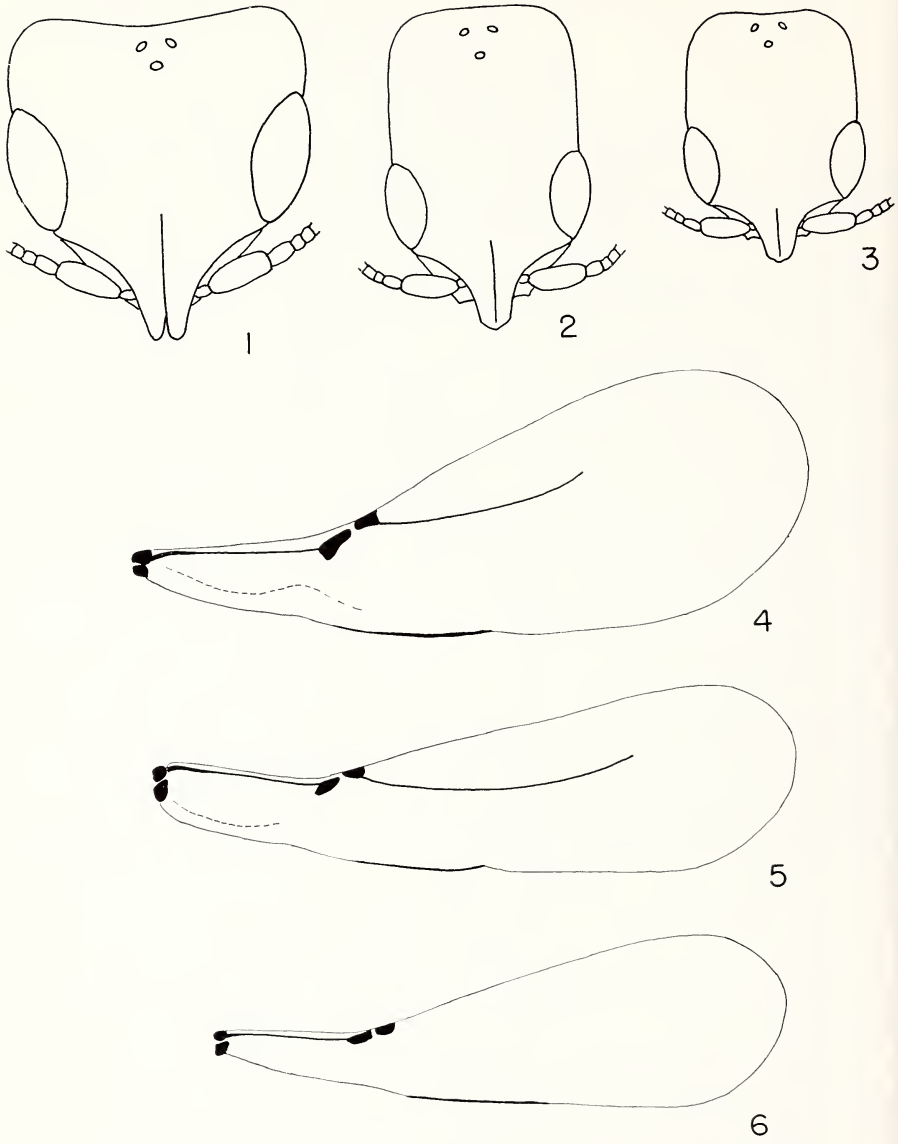
Female.—Length 1.4 mm; fore wing about 1.0 mm. Entirely dark brown except antennae medium brown, tarsi testaceous; wings clear hyaline, veins and stigma brown. Mandibles tridentate; clypeus very short, overhung by the strong frontal process, which is subangulate and slightly reflexed apically, grooved medially. Head elongate, its sides subparallel; width of head 0.62 × length of head; distance from eye tops to vertex crest about 1.5 × eye height; width of front between eyes 1.3 × eye height. Eyes hairy; ocelli in an acute triangle, ocello-ocular line about 2.5 × width of ocellar triangle. First four antennal segments in a ratio of about 10:3:1:2. Front and thoracic dorsum shining but with fine, reticulate sculpturing; notauli absent; propodeum polished and without sculpturing. Wings very slender; fore wing without closed cells; radius long, evenly curved, about 1.4 × as long as distance from wing base to stigma. Abdomen shining, very strongly depressed.

Male.—Length 1.7 mm; fore wing 1.3 mm. Coloration as in female. Mandibles and clypeus as in female, frontal process slightly shorter and more slender, rounded apically; head somewhat shorter and eyes more protuberant, width of head 0.78 × length of head; width of front 1.2 × eye height. Ocelli slightly larger than in female, front angle slightly less than a right angle, ocello-ocular line 1.6 × width of ocellar triangle. Antennae longer than in female, moniliform, first four segments in a ratio of about 10:6:3:4. Other features essentially as in female.

Paratypes.—3♀♀, 1♂, same data as type [U.S. Nat. Mus.]. 1♀, BRAZIL: Represa Rio Grande, Guanabara, Oct. 1969 (M. Alvarenga) [Canad. Nat. Coll.].

Variation.—The topotypic specimens show only minor variation in size, color, and standard measurements. The female from Brazil is paler in color, being wholly castaneous, but it is otherwise so similar that I cannot believe it represents a different species; in this specimen width of the head is 0.65 × length of head, width of front 1.2 × eye height.

Remarks.—This species may prove to be widespread in the American tropics and subtropics; on the basis of presently available material, it is very difficult to judge its total distribution.



Figs. 1–3. Heads of *Prorops* females, drawn to same scale: 1, *P. nasuta* Waterston; 2, *P. petila*, n. sp.; 3, *P. obsoleta*, n. sp. Figs. 4–6. Forewings of *Prorops* females, drawn to same scale: 4, *P. nasuta* Waterston; 5, *P. petila*, n. sp.; 6, *P. obsoleta*, n. sp.

Prorops obsoleta, n. sp.
(Figs. 3, 6)

Holotype.—♀, TRINIDAD: Curepe, Sta. Margarita, Circular Rd., 26 Sept.–26 Oct. 1974 (E. D. Bennett).

Allotype.—♂, same data except dated 28 Jan.–9 Feb. 1974 [both Canad. Nat. Coll.].

Female.—Length 1.0 mm; fore wing 0.8 mm. Head and thorax castaneous, abdomen testaceous; antennae, tibiae, and tarsi straw-colored, coxae and femora pale castaneous; wings clear hyaline, veins brown. Mandibles similar to those of *petila*; frontal process extending well beyond clypeus, apex weakly trifid and slightly reflexed, upper surface with a median, linear groove. Sides of head subparallel, but head less elongate than in *petila*, width 0.72 × length; distance from eye tops to vertex crest about 1.3 × eye height; width of front between eyes 1.6 × eye height. Eyes hairy; ocelli in an acute triangle, ocello-ocular line about 2.2 × width of ocellar triangle. First four antennal segments in a ratio of about 9:4:2:2. Front polished, delicately alutaceous on lower half but smooth above; dorsum of thorax and propodeum polished, nonalutaceous except pronotum with weak surface sculpturing; notauli present as linear streaks. Wings slender, fore wing with only a single vein which stops at the stigma, radius entirely absent. Abdomen shining, much less strongly depressed than in *petila*.

Male.—Size, color, and surface sculpturing as in female; frontal process somewhat more slender than in that sex, and head shorter, width 0.85 × length; width of front 1.45 × eye height; ocello-ocular line 1.5 × width of ocellar triangle. Antennae longer than in female, moniliform, first four segments in a ratio of about 7:3:1:1. Wings as in female.

Paratype.—1♀, TRINIDAD: Curepe, CIBC Lab. grounds, 26 Feb.–13 Mar. 1974 (E. D. Bennett) [Canad. Nat. Coll.].

Remarks.—This minute species appears closely related to *petila* despite the total absence of the radius of the fore wing.

Prorops nasuta Waterston
(Figs. 1, 4)

Remarks.—Waterston's (1923) description of this species is detailed and well illustrated. In addition to material from near São Paulo, Brazil, where the species was introduced from Africa, I have seen the following specimens: 1♀, JAMAICA: 1929 (G. Russo, *ex Stephanoderes seriatus*) [U.S. Nat. Mus.]; 1♀, CUBA: Atabay, Habana, Aug. 1973 (L. Arnos, en fruto de *Moringa oleifera*) [Acad. Ciencias Cuba]; 1♂, CALIFORNIA: Riverside, 6 Oct. 1940 (P. H. Timberlake, on *Baccharis emoryi*) [Univ. Calif. Riverside]. These three specimens all agree closely with Brazilian and African material.

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BOOK REVIEW

E. C. G. Pinhey. *Moths of Southern Africa.* Descriptions and color illustrations of 1,183 species. 273 p. Tafelberg, Cape Town. Distributed by Entomological Reprints Specialists, P.O. Box 77971, Los Angeles, Calif. $39.95.

The author, an entomologist at the National Museum in Bulawayo, Northern Rhodesia, has described the more familiar moth species, as well as those of economic importance, such as army worms, codling moths, cutworms, treeborers and bollworms. The 63 color plates provide beautiful illustrations. There are general remarks on biology, habits and behavior, and suggestions for beginners on how to collect and preserve specimens. A good glossary, indexes to pests and to host plants, references, and a general index complete the volume. The publication has been subsidized by the South African Coal, Oil and Gas Co. as well as a number of individuals, which explains its comparatively low price, considering the abundance of color plates. While the emphasis is on species from Southern Africa, some moths are included that occur north of the Zambezi River and there are descriptions of a few that are cosmopolitan. This book will be a useful addition to libraries in departments of entomology as well as to personal libraries of lepidopterists.

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A HOMONYMIC SYNONYM IN *CALLIBAETIS* (EPHEMEROPTERA: BAETIDAE)

Michael D. Hubbard and George F. Edmunds, Jr.

Abstract.—The mayfly *Callibaetis vitreus* Navás, 1919 is a homonymic synonym of *Callibaetis vitreus* Navás, 1915.

L. Navás (1915) described a new species of mayfly from Argentina based on the subimago and male imago as *Callibaetis vitreus.* In 1919 Navás described another new Argentine species from the female subimago, also calling it *Callibaetis vitreus.* One of us (GFE) has examined the types of these mayflies deposited in the Museo de La Plata, Argentina. These type specimens apparently belong to the same species. *Callibaetis vitreus* Navás, 1919 is thus in the remarkable position of being both a junior synonym and a junior homonym of *Callibaetis vitreus* Navás, 1915. (*Callibaetis vitreus* Navás, 1919 = *Callibaetis vitreus* Navás, 1915: NEW SYNONYMY.)

G. S. Dodds (1923) also used the specific epithet *vitreus* for a new species of mayfly belonging to the genus *Callibaetis* from Colorado, USA (misspelled *vitrea*). This species was renamed *Callibaetis doddsi* by J. R. Traver (1935).

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INSECTICIDE SUSCEPTIBILITY IN NEW JERSEY GYPSY MOTH (LEPIDOPTERA: LYMANTRIIDAE) POPULATIONS

Napoleon C. Respicio and Andrew J. Forgash

Abstract.—Third instars of *Lymantria dispar* (L.) reared from egg masses collected from eight field locations covering northern, central and southern New Jersey were compared for susceptibility to insecticides by topical application. There was no difference in acephate tolerance for three widely separated populations nor in DDT tolerance in the two populations (northern and southern) tested. Significant differences in carbaryl susceptibility were detected for several of the eight collections but the differences were small (2-fold, or less) and were not considered indicative of incipient resistance.

In a study of the relative toxicity of different types of insecticides to gypsy moth, *Lymantria dispar* (L.) (Tomlin and Forgash, 1972), it was found that larvae from one area in southern New Jersey were ca. 4 times and 11 times as tolerant to carbaryl at the LD_{50} and LD_{95} levels, respectively, as were specimens from the northern part. There also seemed to be a high tolerance to DDT (LD_{50} 5 μg/larva) although comparison tests were not run with northern larvae at that time. Later, Tomlin (pers. comm.) showed that Canadian larvae were comparable to northern New Jersey larvae in susceptibility to carbaryl and considerably less tolerant than southern larvae to DDT. These findings indicated that changes in insecticide tolerance may have occurred in some areas of New Jersey and this prompted a state-wide survey of gypsy moth populations to detect the presence of incipient resistance. The results of the survey are presented here.

Materials and Methods

Gypsy moth egg masses were collected during January 1972 from different locations in New Jersey (Fig. 1). These were used soon after collection or kept in cold storage (below 4°C) until needed. To prepare the eggs for hatching, they were separated from the mass, moistened with water, treated with 10% Clorox® for 30 min with constant shaking, rinsed with flowing water for 15 min, and spread on absorbent paper to dry. The eggs were then placed in hatching dishes and kept at room temperature. Newly-hatched larvae were transferred to sterile petri dishes lined with filter paper and provided with a modified version of the artificial diet of ODell and Rollinson (1966), i.e., the replacement of fructose with sucrose, elimination of alphacel, methyl linoleate and aureomycin, and the addition of sodium

propionate for mold inhibition. The larvae were held until the 3rd instar at 25°C, 50 to 70% RH, and a 14-h light-dark cycle.

The insecticide susceptibilities of the different collections were determined by topical application to 3rd instars. Carbaryl, acephate, or DDT were applied in one-μliter drops of acetone to the dorsum of the thorax. Ten individuals were treated at each of four or five concentrations and held at 21–24°C in petri dishes lined with filter paper and provided with a block of artificial diet. All tests were repeated four or five times. Dosage-mortality curves were constructed from 24-h mortality data, using the probit analysis method of Finney (1952). Carbaryl (99+% purity) was obtained from Union Carbide Corp.; acephate from Chevron Chemical Co.; and p,p′-DDT from City Chemical Corp., New York, N.Y.

Results and Discussion

Table 1 presents LD_{50} and LD_{95} values and fiducial limits for topical applications of carbaryl, acephate and p,p′-DDT to 3rd instars from various geographical locations in New Jersey.

For carbaryl, the LD_{50}'s ranged from 0.09–0.16 μg/larva, and the LD_{95}'s from 0.42–0.90. Camp No Be Bo Sco, Zion, and Greenfield larvae appeared slightly more susceptible to carbaryl at the LD_{50} level than Scotts Mt., Smithburg, Manahawkin, or Medford specimens. At the LD_{95} level, the only difference in carbaryl susceptibility among the eight locations occurred with the Lakewood and Scotts Mt. larvae, the latter appearing to be slightly more tolerant.

There were no apparent differences in acephate tolerance (LD_{50}'s 1.67–1.97; LD_{95}'s 3.08–4.99) for the three collections tested from the northern, central and southern portions of the state. DDT was equally toxic to widely separated populations (Scotts Mt. and Greenfield) that differed two-fold in carbaryl susceptibility (DDT LD_{50}'s 0.37–0.42; LD_{95}'s 0.69–0.85).

Although the differences detected in carbaryl tolerance were significant, they represent factors of only two or less and are not considered to be indicative of incipient resistance.

Acknowledgment

We thank Mr. Robert Bulaam and Mr. Kenneth Sponenbergh of the New Jersey Department of Agriculture for assistance in collecting gypsy moth egg masses and Mr. Robert Chianese of the Beneficial Insect Laboratory, N.J. Dept. Agric. for technical advice on gypsy moth rearing.

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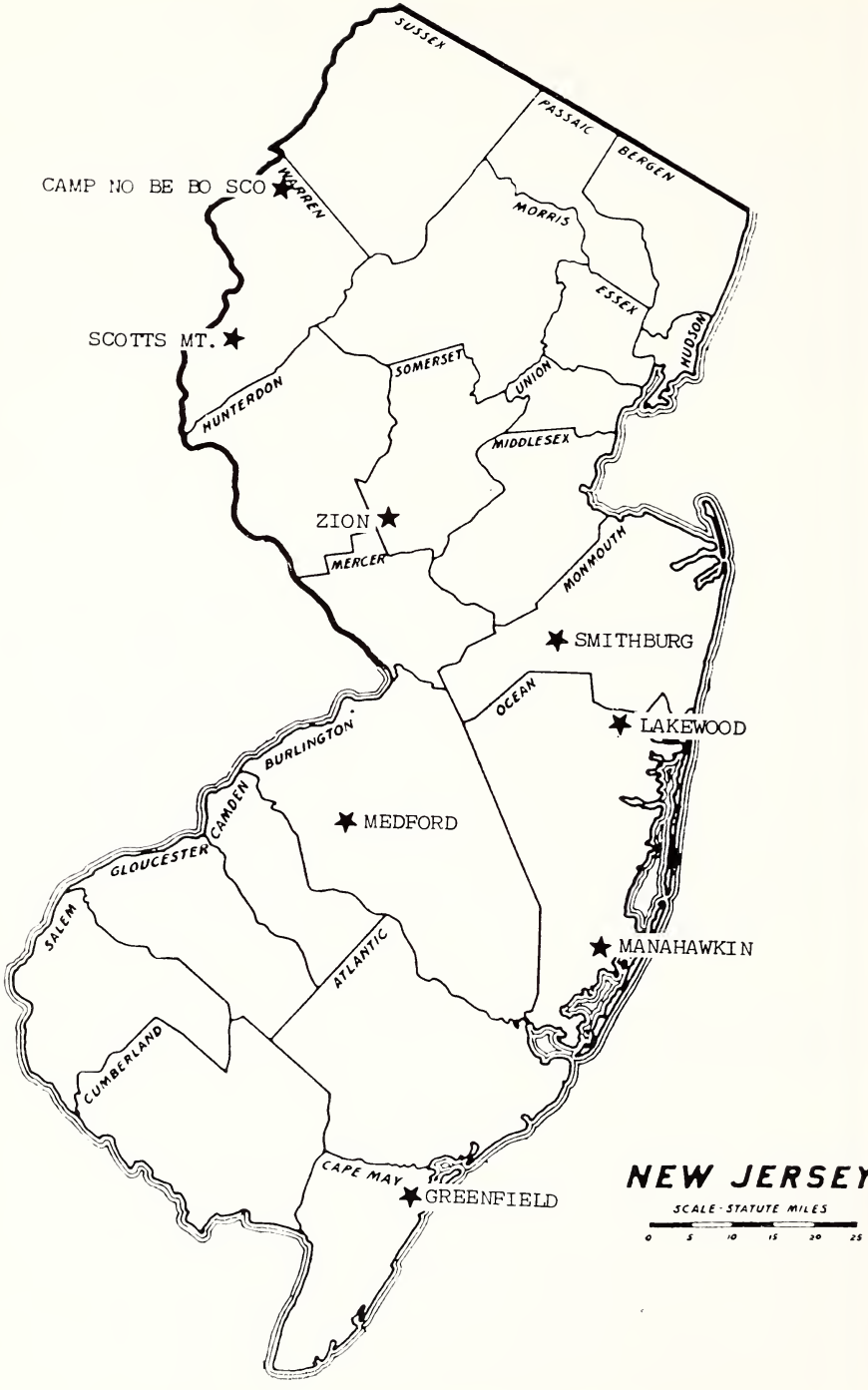
SUSSEX
PASSAIC
BERGEN
CAMP NO BE BO SCO
WARREN
MORRIS
ESSEX
HUDSON
SCOTTS MT.
SOMERSET
UNION
HUNTERDON
MIDDLESEX
ZION
MERCER
MONMOUTH
SMITHBURG
OCEAN
LAKEWOOD
BURLINGTON
CAMDEN
MEDFORD
GLOUCESTER
SALEM
ATLANTIC
MANAHAWKIN
CUMBERLAND
CAPE MAY
GREENFIELD
NEW JERSEY
SCALE - STATUTE MILES
0 5 10 15 20 25

Table 1. Contact toxicity of carbaryl, acephate and p,p'-DDT to 3rd instars of the gypsy moth from different locations in New Jersey.

Location	LD_{50}[a] (μg/larva)	Fiducial limits $P = 0.05$	LD_{95}[a] (μg/larva)	Fiducial limits $P = 0.05$
		Carbaryl		
Northern				
Camp No Be Bo Sco	0.08	0.07–0.10	0.58	0.40–0.85
Scotts Mt.	0.16	0.13–0.19	0.90	0.61–1.33
Central				
Lakewood	0.12	0.10–0.14	0.44	0.32–0.60
Zion	0.11	0.08–0.12	0.57	0.40–0.83
Smithburg	0.16	0.13–0.19	0.85	0.56–1.28
Southern				
Manahawkin	0.13	0.11–0.16	0.67	0.48–0.95
Greenfield	0.09	0.07–0.11	0.42	0.28–0.65
Medford	0.16	0.13–0.19	0.81	0.56–1.18
		Acephate		
Northern				
Scotts Mt.	1.97	1.72–2.24	4.99	3.44–7.25
Central				
Smithburg	1.67	1.47–1.89	4.56	3.15–6.57
Southern				
Medford	1.87	1.75–2.00	3.08	2.69–3.52
		p,p'-DDT		
Northern				
Scotts Mt.	0.42	0.38–0.46	0.85	0.69–1.05
Southern				
Greenfield	0.37	0.35–0.40	0.69	0.60–0.80

[a] Mortality 24 h after treatment.

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Fig. 1. Locations of gypsy moth egg mass collections in New Jersey.

Tomlin, A. D., and A. J. Forgash. 1972. Toxicity of insecticides to gypsy moth larvae. J. Econ. Entomol. 65:953–954.

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THE GYPSY MOTH AND ITS INSECT PARASITOIDS ON LONG ISLAND, NEW YORK

Mervyn A. Kamran

Abstract.—Larvae, pupae, and egg masses of the gypsy moth, *Lymantria dispar* (L.), were collected from localities on Long Island, New York, and observed in the laboratory for the emergence of their insect parasitoids. Seven primary and five secondary parasitoids were recorded. A braconid, *Apanteles melanoscelus* (Ratz.), and a tachinid, *Blepharipa pratensis* (Meig.), were the most abundant of the primary parasitoids.

The gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), is a serious defoliator of trees, especially various species of oaks on Long Island, New York. The first record of its presence on Long Island was the discovery in June, 1921, of a small infestation at Greenport (Burgess, 1923). In July of the same year, another infestation was reported from Patchogue. About the same time small infestations were discovered in Prospect Park, Kew Gardens and Roslyn. All of these infestations were thoroughly treated by the Bureau of Entomology, United States Department of Agriculture. The pest was greatly reduced, but not exterminated (Burgess, 1923).

For the next three decades the gypsy moth remained a relatively minor pest on Long Island. Then during the middle fifties it increased tremendously in numbers and became a serious threat. Initially, wholesale spraying of infested woodlands was considered to be the best method of combating this pest. In 1957 the entire eastern half of Long Island was sprayed with DDT (Brewster, 1970).[1] However, in the same year environmentalists instituted court action to stop the use of DDT. During the following decade the pest population built up to numbers which caused repeated defoliations of trees in Long Island woodlands.

Not only is there interest in saving our trees and shrubs from unnecessary defoliations, but in many areas the caterpillars become abundant enough to pose a health and allergy problem for the burgeoning human population of eastern Long Island. Millions of the small, hairy caterpillars get blown by the wind and enter homes, cars, etc., thus making life miserable.

In the last few years a carbamate insecticide, carbaryl, has been used to combat this pest. Carbaryl is biologically safer than DDT, and thus represents a considerable improvement on similar efforts in previous years. However, it is a non-selective pesticide and kills many different kinds of insects. Some of these insects that are decimated by carbaryl are parasitic on the gypsy moth. If allowed to flourish, these parasitoids can be sig-

nificant control agents. Their destruction by pesticides has probably contributed significantly to the perpetuation of large populations of the gypsy moth on Long Island.

The key to the understanding of gypsy moth population dynamics on Long Island probably lies in a thorough study of the interplay among the various environmental and biological control factors operating on the gypsy moth. A first step in this direction would be the identification of some of the biological factors, e.g., parasitoids, predators and pathogens. The next step would involve the elucidation of the role played by these organisms in controlling the pest.

The significant role played by parasitoids in regulating populations of their hosts has been amply documented (DeBach, 1974). Since the arrival of the gypsy moth in Massachusetts in 1869, considerable time and money have been spent by the federal and the state governments in the Northeast in importing exotic parasitoids (Sabrosky and Reardon, 1976), and supplementing their efforts with other cultural and biological methods. No concerted work of this type has ever been carried out on Long Island. During the course of this investigation it became obvious that on Long Island the gypsy moth parasitoids were quite active as well as widespread. However, there is very little first hand information available on the kinds of parasitoids to be found on Long Island. Nothing is known about their abundance and effectiveness in regulating the pest population.

During 1970–72 the effectiveness of the gypsy moth parasitoids was investigated in selected localities in Suffolk County which occupies the more heavily infested eastern half of Long Island. This publication presents the results of this study.

Sampling Areas

Samples were collected from various heavily infested localities. The pest has undergone great, and not completely understood, fluctuations in its population size in individual localities. Consequently, the sampling sites were changed from year to year (Fig. 1).

Field Sampling Techniques

Gypsy moth larvae were collected at weekly intervals by trapping them in specially constructed burlap band traps. The method of constructing these traps has been described elsewhere (Kamran, 1968). The traps were opened periodically and the hiding larvae collected. The traps were also found to be excellent for collecting pupae and puparia of parasitoids of the trapped caterpillars.

Collections of pupae were made from the traps as well as nearby hiding places.

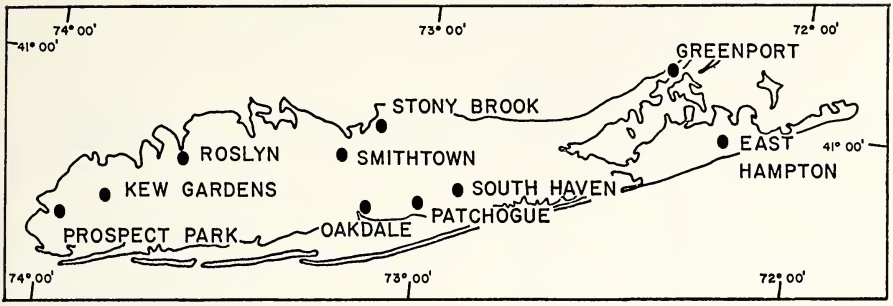

Fig. 1. Map of Long Island, New York, showing the various localities referred to in the text.

The traps also facilitated collections of egg masses. Gypsy moth females, after crawling out of their pupal cases in the traps, mated and deposited their eggs on the bark in the vicinity of the traps. The egg clusters were collected by scraping them off the bark with a sharp knife.

Laboratory Handling Techniques

Egg masses were placed individually in test tubes for observation, and a record of the percent parasitization of the masses was kept.

Field-collected larvae were placed in 6 in. × 3 in. circular cardboard containers with removable tops. A few holes were made in the tops to provide ventilation. A fresh supply of clean oak leaves was put in each container on alternate days. Thousands of field-collected larvae were thus successfully reared in the laboratory.

The larvae were examined closely for any signs of having been parasitized. Upon the emergence of parasitoids, i.e., the formation of their external pupae or puparia, they, as well as the host larvae, were transferred to individual petri dishes. This made possible closer observations and facilitated collection of adult parasitoids. A record was kept of the numbers and kinds of parasitoids that were obtained in this manner. The parasitoids were sent to the Systematic Entomology Laboratory, United States Department of Agriculture, Beltsville, Maryland, for identification.

Field-collected pupae were placed in petri dishes for observation. A record of the numbers and kinds of the emerging parasitoids was kept. Moths that emerged were destroyed.

Results

The results are shown in Tables 1 and 2. The method of calculating percent parasitism has been described elsewhere (Kamran and Raros, 1969). The following parasitoids were recorded:

Table 1. Results of laboratory rearing of weekly samples of the gypsy moth from localities in Suffolk County, Long Island, New York 1971–72.

Date & week of	No. of larvae Collected	Survived	Parasitized	% Parasitism	Dominant Parasites
1971 Oakdale and South Haven, N.Y.					
May 24	207	133	1	0.8	
31	143	93	1	1.1	*A. melanoscelus*
Jun. 7	900	575	7	1.2	
14	118	85	4	4.7	
21	244	160	22	13.8	
28	75	16	9	56.3	*B. pratensis*
Jul. 5	56(pupae)	26	14	53.9	
Total	1,743	1,088	58	5.3	
1972 Stony Brook, Smithtown and East Hampton, N.Y.					
Jun. 6	670	601	104	17.3	
13	500	439	20	4.6	*A. melanoscelus*
20	300	282	24	8.5	
27	100	87	3	3.4	
Jul. 4	70(pupae)	60	11	18.3	*B. pratensis*
11	239(pupae)	220	11	5.0	
Total	1,879	1,689	173	10.2	
Grand Total	3,622	2,777	231	8.3	

1. *Apanteles melanoscelus* (Ratz.) is a small braconid parasitoid of the gypsy moth larvae during the 1st 4 instars. It was first imported in 1911 from Sicily (Clausen, 1956). It seems to have spread all over Long Island and is now well-established here. Since it has at least two generations a year, it responds very favorably to increases in host density. In Smithtown in early June 1972 29.2% of young larvae were parasitized by it. During the same time 20.7% of the larvae in Stony Brook were parasitized by it. It was the only parasitoid obtained from the field-collected larvae in the first four samples each year (Table 1).

Apanteles melanoscelus is, in turn, parasitized by a number of different insects. These hyperparasites are themselves fairly widespread and no doubt contribute to the general ineffectiveness of *A. melanoscelus*. One of these is *Gelis obscurus* (G.), an ichneumonid, reared from cocoons of *A. melanoscelus* collected in Stony Brook in June 1972. A few individuals of *Gelis* sp. were also reared from cocoons of *A. melanoscelus* collected from Oakdale in 1971 and Smithtown in 1972.

Another hyperparasite is *Eurytoma appendigaster* (Swederus) which seems to be widespread on Long Island. It was reared from cocoons of

Table 2. Total parasitism in field-collected gypsy moth material. Suffolk County, Long Island, New York 1970–72.

	Locality & year	Nos. Collected	Nos. Survived	Nos. Parasitized	% Parasitism
I.	Larvae:				
	Oakdale 1971	513	306	4	1.3
	South Haven 1971	1,174	756	40	5.3
	Stony Brook 1972	980	902	89	9.9
	East Hampton 1972	340	287	13	4.5
	Smithtown 1972	250	220	49	22.3
	Total	3,257	2,471	195	7.9
II.	Pupae:				
	South Haven 1971	56	26	14	53.8
	Stony Brook 1972	21	20	2	10.0
	East Hampton 1972	218	200	9	4.5
	Smithtown 1972	70	60	11	18.3
	Total	365	306	36	11.8
III.	Egg Masses:				
	South Haven 1970	159	159	146	91.8
	Oakdale 1970	160	160	157	98.1
	South Haven 1971	98	98	87	88.8
	Oakdale 1971	54	54	0	—
	East Hampton 1972	115	115	49	42.6
	Stony Brook 1972	65	65	56	86.2
	Total	651	651	495	76.0

A. melanoscelus collected from South Haven in 1971 and 1972, and Stony Brook in 1972.

Field-collected cocoons of *A. melanoscelus* from South Haven in 1971 and Smithtown in 1972 yielded many individuals of *Ooencyrtus kuwanai* (Howard).

2. One individual of *Theronia* sp. was reared from a gypsy moth pupa collected from Oakdale in 1971.
3. *Blepharipa pratensis* (Meig.). This tachinid was originally established in the United States from a culture imported from southern France in 1909 (Howard and Fiske, 1911). It is now probably the most abundant parasitoid of the gypsy moth on Long Island. Just as early instar field-collected larvae of the gypsy moth yield mostly *A. melanoscelus*, older field-collected larvae and pupae yield mostly *B. pratensis* (Table 1). It was recovered from all the localities that were sampled

each year. The highest rate of parasitization was 36.0% in larvae collected in late June 1971 from South Haven. It has but a single generation a year, yet in heavily infested areas it becomes so abundant that it is relatively easy to find its puparia in the litter at the bases of the trees. A large number of its puparia were also collected from the traps.

4. *Compsilura concinnata* (Meig.). This tachinid is another European import which is apparently quite widespread on Long Island. It was reared from gypsy moth larvae collected from Oakdale in 1971 and East Hampton in 1972. The latter site yielded a parasitization rate of 15.0%.
5. A few tachinid puparia belonging to *Exorista* sp.? and Genus Sp.? possibly *Parasetigina agilis* (R.-D.) were also reared from gypsy moth larvae collected from East Hampton in 1972.

   Field-collected puparia of tachinid flies often yielded the chalcid, *Brachymeria compsilurae* (Crawford). In 1972, 5.0% of the puparia collected from East Hampton were parasitized by it.
6. *Brachymeria intermedia* (Nees). This chalcid was among the first to be introduced into the United States (Howard and Fiske, 1911), but has only recently been reported to become established (Leonard, 1966). It seems to become abundant in heavily infested areas. In 1971, 5.0% of the pupae in South Haven were attacked by it. In 1972, 15% of the pupae collected from East Hampton were parasitized by it.
7. *Ooencyrtus kuwanai* (Howard). This encyrtid was originally imported in 1909 from Japan (Fiske, 1910). On numerous occasions this parasitoid has been released on Long Island, and is now quite widespread. It has many generations per year. It was the only parasitoid reared from field-collected eggs of the gypsy moth. It attacked 98.1% of the egg masses in Oakdale in 1970. The following year it had completely disappeared. This was most probably due to the heavy applications of carbaryl (for gypsy moth control) and other chemicals (for mosquito control) in the Oakdale area in the summer of 1971.

   Because the female posseses an ovipositor that is too small to reach all of the eggs in an egg mass, a majority of the eggs in each egg mass escape parasitization. In this study, however, the extent of parasitization of the individual eggs in the egg masses was not investigated. Its inability to parasitize all the eggs in an egg mass, and the fact that it is a hyperparasite of *A. melanoscelus*, detract considerably from its overall usefulness.

Discussion

The results of this study indicate that on Long Island there is a well-established spectrum of parasitoids, both dipterous and hymenopterous, attacking all the developmental stages of the gypsy moth. *O. kuwanai*

attacks the egg masses, *A. melanoscelus* is the dominant parasitoid during the early larval instars and *B. pratensis* becomes the premiere parasitoid during the late larval instars. Similar results have been reported from upstate New York (Tigner, 1974). The desirability of having such a "sequence of parasites" attacking all the stages of the pest was first pointed out by Fiske (1910) in his work with the gypsy moth in Massachusetts. Since all of the parasitoids mentioned above are imported species, it is obvious that a good beginning has been made toward fulfilling the requirements of Fiske's "sequence theory."

However, much more work remains to be done. This is shown clearly by the low overall rates of parasitization (Table 2). There are many parasitoids that, during the early years of importations, could not be introduced successfully due to difficulties and delays in transportation. Now as many of these parasitoids as possible should be introduced. Even if a certain species is known to have become established here, its introductions from other localities in its original distributional range may prove useful. Such introduced geographic and ecological "strains" may become abundant in areas of their preference and prove beneficial.

On Long Island *O. kuwanai* was mass reared and liberated for a number of years by the United States Department of Agriculture. Other than that, efforts to control the pest on Long Island in recent years have, almost exclusively, consisted of annual regimens of large scale aerial spraying operations conducted by the New York State Department of Environmental Conservation. Until recently, no effort had been made to import and utilize other species of beneficial insects in an integrated control program on Long Island.

Since the early sixties, the United States Department of Agriculture, and the cooperating Connecticut Agricultural Experiment Station and the New Jersey Department of Agriculture, have imported, propagated and released a number of parasitoids. Releases have been made in many localities from Maine to North Carolina. On Long Island *Meteorus* sp., *Apanteles* spp., *Parexorista* spp. and *Coccygomimus* spp. were released in 1975, but have not been recovered so far. In 1976, *Apanteles liparides* Bouché, *Meteorus pulchricornis* Wesmael and *Blondelia nigripes* (Fallén) were released (Trotta and Galli, 1976).[2] These releases are expected to be continued for a few years. Results, though necessarily slow in coming, are bound to be beneficial and will help in minimizing the ravages of the pest.

During the last 10 years Long Island has gone through many years of wide-spread defoliation of trees. There are probably many reasons for this state of affairs:

Until the late fifties, regular applications of DDT on Long Island kept the pest under control. During the early sixties (1961–66) Long Island suffered from a severe drought. The dry climate coupled with the absence

of any control measures was probably the cause of a steady build-up in the pest population which resulted in extensive defoliation of trees in the late sixties (1968–70). These years probably saw a considerable increase in parasitoid populations as well. Furthermore, the return to normal weather (i.e., increased precipitation) most likely resulted in an increase in microbial infections in the pest population. These factors probably accounted for the drop in the pest population which occurred in the early seventies. Spraying of carbaryl on Long Island, even though relatively restricted, may have delayed somewhat the recovery of the parasitoid populations. That the parasitoids and other biological control agents had fully recovered by the mid-seventies is evidenced by the fact that in 1974 only 15,000 acres were considered infested heavily enough to warrant spraying as compared to 25,000 acres in 1970. More recently the pest has become even less abundant. In 1975 less than 3,500 acres and in 1976 only 1,700 acres, located mostly in the far eastern part of Long Island, were earmarked for spraying. This gradual, yet dramatic, decline in the pest population occurred at a time when the New York State Department of Environmental Conservation was sharply curtailing its program of aerial sprays. It is obvious that to the natural enemies of the gypsy moth goes some, if not most, of the credit for this decline in the pest population.

Efforts to combat the gypsy moth in the United States have followed a cyclic course in keeping with the ups and downs in the extent of damage done by the pest. As Leonard (1974) has pointed out: ". . . with few exceptions the support for research in any one area closely approximates the curve of the gradations occurring there, resulting in periodic gathering of bits and pieces of information that differ little from that gathered during the previous gradations." What is needed is a concerted and sustained effort aimed at a comprehensive biological study of this pest both here and abroad.

The deleterious effects of various pesticides on the beneficial entomophagous insects have been well documented (DeBach, 1974). It is now clear that the aerial applications of insecticides to woodland areas is a very indiscriminate process. All types of animals are affected, including the pest and the beneficial entomophagous insects. Some of these beneficial insects are hit while on the wing (e.g., almost all larval and pupal parasitoids), some while on the leaves of trees (e.g., pupae of *A. melanoscelus*), others are killed while in the litter on the forest floor (e.g., adults of *O. Kuwanai*, and puparia of *B. pratensis*, etc.).

Aerial spraying of chemicals is, however, much superior to that done from the ground due, among other things, to the fact that it results in the application of much smaller quantities of the chemicals per unit area for comparable control. For speedy relief from the pest it is still one of the best available methods. There are some areas the spraying of which is clearly

in the public interest, e.g., heavily infested recreational and residential areas. However, even in these areas, a multipronged integrated control program using the well-known *Bacillus thuringiensis* and perhaps a pathogenic virus as tactical control agents, and various parasitoids and predators as strategic control agents would prove to be highly effective as well as environmentally impeccable.

It appears that an environmentally sound strategy of gypsy moth control on Long Island should also involve leaving alone large tracts of uninhabited woodlands, even if heavily infested, for parasitoids and predators to maintain their numbers. This is a particularly judicious move in light of the fact that, despite their obvious ecological importance, the trees in Long Island's woodlands have very little commercial value. Consequently, some defoliation, and the resulting loss of tree growth for part of the growing season, can be ignored.

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Footnotes

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BOOK REVIEW

V. B. Wigglesworth. *Insects and the Life of Man.* Collected essays on pure science and applied biology. 217 p. Halsted Press, John Wiley & Sons, N.Y. $12.50.

The volume contains a series of 16 essays and lectures that were originally intended for a general audience. The topics cover the applications of DDT and the balance of nature, malaria transmission and mosquito control, insects and human affairs, and various aspects of insect physiology and development, experimental biology, and Sir Vincent's penetrating discussion of the religion of science. The book is clearly written and by virtue of its breadth and content it forms an ideal text for an advanced graduate student in entomology who seeks to deepen his knowledge in the diverse aspects of insect behavior, biological control, and endocrinology. The book is authoritative, sophisticated and stimulating. It is eminently readable and the personal and frank approach of Wigglesworth will appeal to graduate students not only in entomology but also to all those interested in agriculture and forestry. It will also be of interest to research workers in all fields of biology, veterinary and tropical medicine, and parasitology.

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GENERAL ANATOMICAL FEATURES OF THE GYPSY MOTH LARVA *LYMANTRIA DISPAR* (LINNAEUS) (LEPIDOPTERA: LYMANTRIIDAE)

Francis Eugene Traxler

Abstract.—General anatomical features of the gypsy moth *Lymantria dispar* (Linnaeus) (Lepidoptera: Lymantriidae) reveals a well developed caterpillar. The head capsule shows the frons as being the antennal segment, the epistomal sulcus invaginated internally to form a connection with the tentorium, and the absence of an ecdysial cleavage line. The head capsule does not reveal anterior tentorial pits externally. The maxillolabial-hypopharyngeal complex is attached to the head capsule proper by a membrane and is structurally designed to move independently of other mouth parts. Anatomy of the thoracic and abdominal regions shows a total of twelve segments circumvented with setae arranged in tufts. Segments four, five, ten, and eleven, which are without legs, have twelve hair tufts per segment. Segments with legs (one, two, three, six, seven, eight, and nine) have hair tufts that are reduced on the venter. Segments one, four, five, six, seven, eight, nine, ten, and eleven have paired spiracles. All segments have tubercles which form the base of the hair tuft, and the tubercles are classified in accord with their location on the insect's body: dorsal, dorsol-lateral, ventro-lateral, and ventral. Setae are located on every component structure of the insect's body and are barbed.

Introduction

The gypsy moth, *Lymantria dispar* (Linnaeus), was brought into the United States by an enterprising French scientist in 1869, and since that time it has caused widespread defoliation in the northeastern United States. The defoliation is caused by the larval stages which are capable of doing thousands and sometimes millions of dollars worth of damage each year (Nichols, 1962).

The larvae of *Lymantria dispar* consume a variety of vegetation. In the United States 485 species of plants alone are favorable for food (Forbush and Fernald, 1896). The principal host species is *Quercus*, but as population density increases other species such as *Carpinus*, *Ulmus*, *Populus*, and *Salix* are selectively sought out for food. In high density gypsy moth populations, few plants escape being fed upon.

Currently in the United States the Department of Agriculture Research has a multi-million dollar gypsy moth prevention program underway (Anon, 1973). Guidelines for implementing the program were based on a model worked out by Campbell (1972). The main emphasis is placed on inte-

grated controls and population ecology. This program has produced a considerable amount of information pertinent to the two areas emphasized.

Materials and Methods

Eggs of *Lymantria dispar* (Linnaeus) that had been disinfected were obtained from the Connecticut Agriculture Experimental Station, New Haven, Connecticut. They were placed in petri dishes for hatching and development.

After hatching, the young larvae were fed a diet of premixed food obtained from *Bio Service Inc.*, Railroad Avenue, Frenchtown, New Jersey. They also were fed a wheat germ diet formulated by Magnoler (1970). In both cases the food was a gel which was affixed to the petri dish cover. Attachment of the food to the cover prevented contamination by frass. The food was replaced as necessary when dehydrated and consumed.

The fourth instar larvae were used for anatomical study. They were initially frozen, and then observed under a wide-field microscope at a magnification of 50× for study of general external anatomy. Additional larvae were prepared for more detailed studies under the scanning electron microscope (SEM) by critical drying techniques worked out by Anderson (1951).

Critically dried specimens were mounted on aluminum stubs. Because of their hirsute character, the larger specimens had to be grounded by connecting a wire from the specimen to the stub in order to retard charging (Figs. 23 and 26). The specimens were placed in a vacuum chamber and coated with gold by direct current sputtering. They were removed for observation and photographing by the ETEC Corp. (California) Autoscan SEM. Large specimens were manipulated at an unusual working distance of 30 mm because of their size.

Direct photographs were obtained by using polaroid 55 film with positive print and permanent negative. These photographs were then dry mounted to mount boards. The mount boards with the photographs affixed were photographed on 8½ × 11 prints, and the prints were inserted in the text.

A code at the bottom of each photograph gives information related to the following: magnification, kilovolts, working distance, negative number, and numerical sequence of the photograph.

The magnification is indicated by the first set of numbers. In Fig. 1, the first set of numbers may be interpreted by placing one zero after the 02. Thus the magnification of Fig. 1 would be 20 times. The number after the hyphen indicates the number of zeros to be placed after the number preceding the hyphen. For example, Fig. 2 would have a magnification of 60 times, Fig. 3, 100 times, and Fig. 18, 12,000 times.

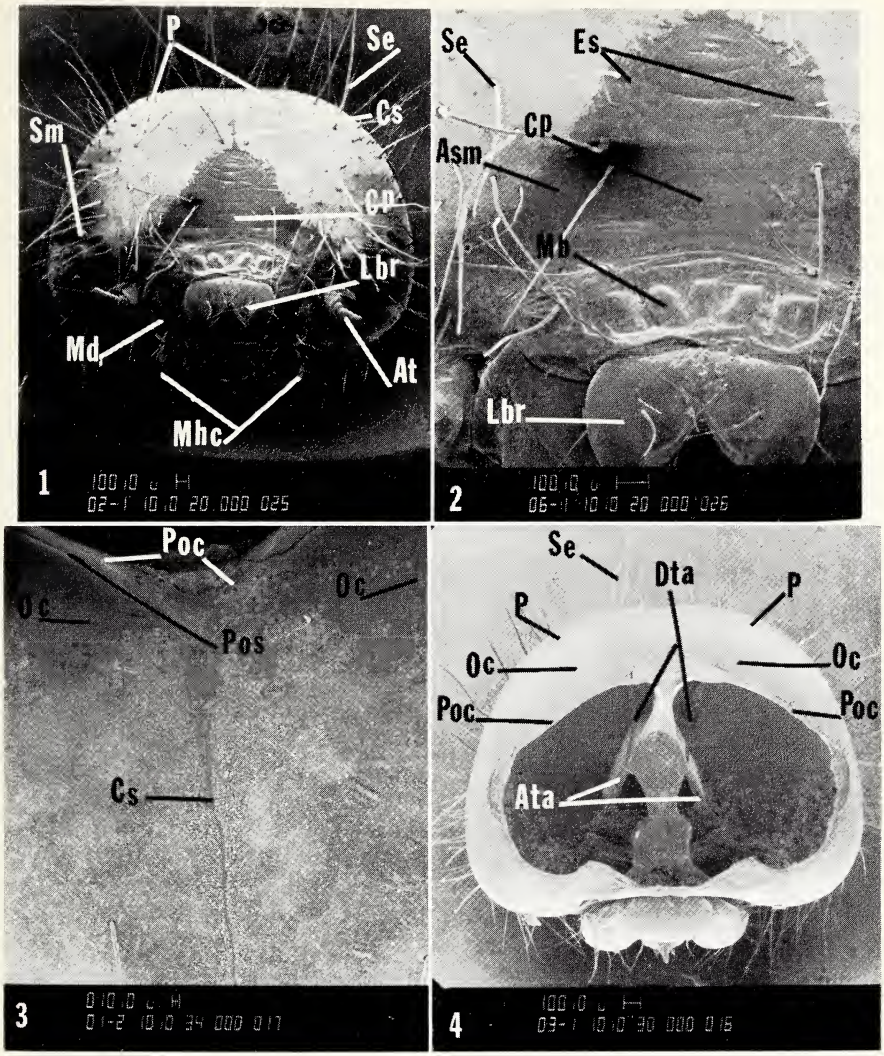

PLATE 1

Fig. 1. Anterior view of a cast head capsule of the fourth instar of *Lymantria dispar*. At, antenna; Cp, clypeus; Cs, coronal sulcus; Lbr, labrum; Md, mandible; Mhc, maxillolabial-hypopharyngeal complex; P, parietals; Se, seta; Sm, stemma. 20×.

Fig. 2. Frontal area of a cast head capsule of the fourth instar of *Lymantria dispar*. Asm, antennal segment; Cp, clypeus; Es, epistomal sulcus; Lbr, labrum; Md, mandible; Se, seta. 60×.

Fig. 3. Dorsal view of a cast head capsule of the fourth instar of *Lymantria dispar*. Cs, coronal sulcus; Oc, occiput; Poc, postocciput; Pos, postoccipital suture. 100×.

Fig. 4. Posterior view of a cast head capsule of the fourth instar of *Lymantria dispar*. Ata, anterior tentorial arms; Dta, dorsal tentorial arms; Oc, occiput; P, parietals; Poc, postocciput; Se, seta. 30×.

The second number indicates the amount of voltage used to operate the SEM in kilovolts.

The third number is the working distance, in millimeters, at which the specimen was photographed.

The fourth number is the negative number.

The fifth number indicates the sequence in which the photograph was taken.

The number to the left of the bar graph indicates the length of the graph in microns.

Results and Discussions

Head Capsule Anatomy

Frontoclypeal Area.—The frontocylpeal area of the head is typically the facial region between the antennae (or between the post frontal sutures when the latter are present) and the base of the labrum. In caterpillar larvae the frons is transformed into the shape of an inverted Y (Snodgrass 1935). However, Ferris (1943) stated that the frons is actually the antennal segment due to the fact that the antennae are vestigial, and have lost their point of articulation with the antennal segment and arise from the basimendibular membrane. In *Lymantria dispar* there was evidence to support the antennal segment term applied by Ferris. The antennae were much reduced and appeared to serve little function in feeding or as sensory devices. Also the post frontal suture was virtually nonexistent.

Cook (1944) indicated that the head of dipterous larva retains the post frontal suture and at least part of the antennal segment. He also stated that the epistomal suture has pushed far back on the head and has become confluent with the postfrontal suture posteriorly—thus squeezing out the antennal segment. The epistomal sulcus of *Lymantria dispar* has been invaginated internally to form a connection with the tentorium and, therefore, may serve to reduce the antennal segment by a similar squeezing out process.

The terms suture and sulcus are used here, since the head is a continuously sclerotized capsule marked by a number of grooves. These grooves are most commonly called sutures, but Snodgrass (1960) indicated that the term suture should imply lines of fusion between two formerly distinct plates. He recommended that grooves of purely functional origin be called sulci.

Most immature insects have a line along the dorsal midline of the head which branches into two lines on the face to form the characteristic inverted Y. Chapman (1969) stated that this line is simply a line of weakness along which the cuticle splits during molting, and it is termed the

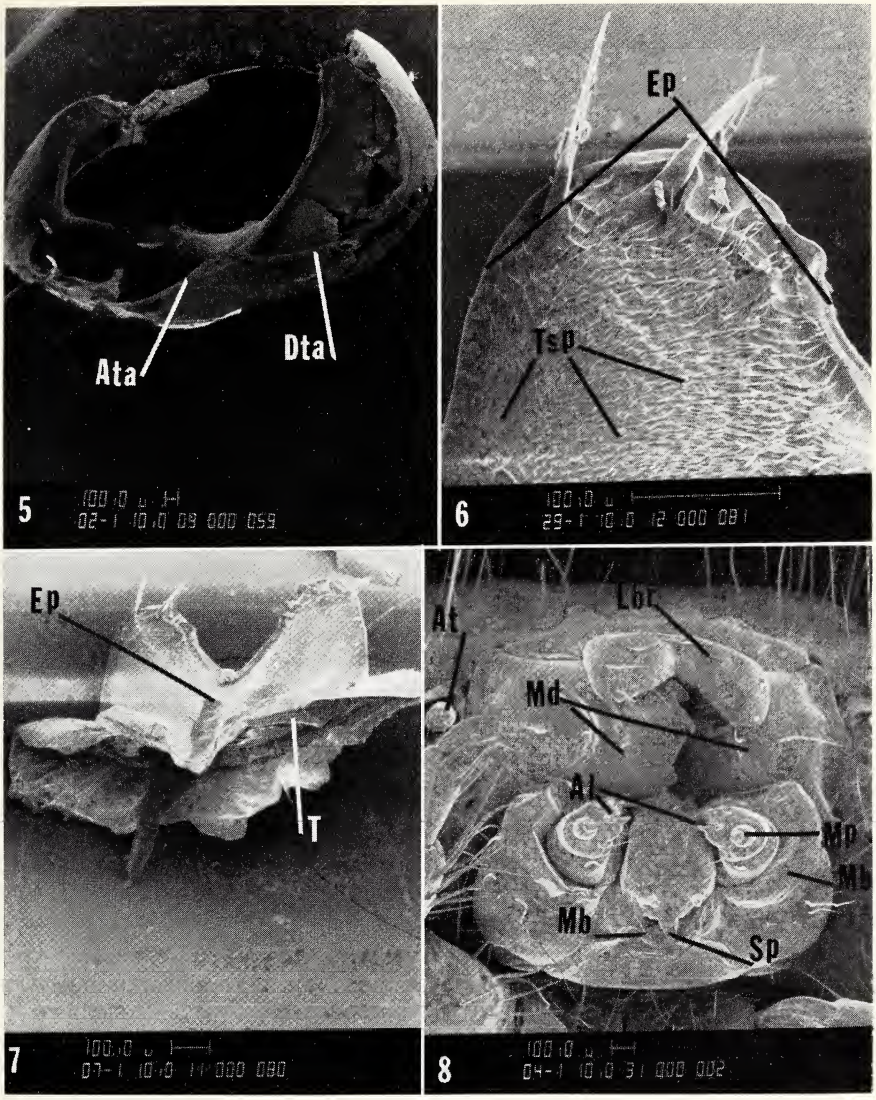

PLATE 2

Fig. 5. Lateral view of a dissected cast head capsule of the fourth instar of *Lymantria dispar*. The Ata, anterior tentorial arms are intact but the Dta, dorsal tentorial arms have been pushed from their posterior attachment during ecdysis. 20×.

Fig. 6. Lateral portion of the epipharynx of the fourth instar of *Lymantria dispar*. Ep, epipharynx; Tsp, taste sensing papillae. 290×.

Fig. 7. Epipharynx detached from fourth instar head capsule of *Lymantria dispar*. Ep, epipharynx; T, torma. 70×.

Fig. 8. Ventral view of a cast head capsule of the fourth instar of *Lymantria dispar*. Al, accessory lobe; At, antenna; Lbr, labrum; Mb, membrane; Md, mandible; Mp, maxillary palpus. 40×.

ecdysial cleavage line. However, the head capsule of *Lymantria dispar* larvae has no ecdysial cleavage line, because the head capsule is cast intact, and the line (Fig. 3) was found to be connected by a thin membrane (Fig. 5) to the tentorium. Therefore, it meets the criterion of the term sulcus.

The clypeus is the facial area of the cranium just above the labrum contained within the epistomal sulcus. The clypeus was much better defined in *Lymantria dispar* than the antennal segment. However, the epistomal (Fig. 2) appeared to fade out about halfway down the clypeus but internal observations of a cast head capsule (Fig. 4) showed the invagination along the epistomal sulcus continuing down to a point just medial to the anterior articulation of the mandibles. Therefore it established the clypeus as the facial area just above the labrum contained within the epistomal sulcus. Snodgrass (1928) indicated that a facial sulcus which contains the anterior tentorial pits is usually identified as the epistomal sulcus. Applegarth (1939) showed that the larva of *Apterobittacus apterus* (MacLachlan) have anterior tentorial pits located lateral to the epistomal sulcus. DuPorte (1946) contradicted Snodgrass by stating that the anterior tentorial arms migrate dorsally in Acrididae and related Orthoptera along the frontogenal and not the frontoclypeal sulcus. The larva of *Lymantria dispar* was found to have the base of the anterior tentorial arms attached to the invaginated portion of the epistomal sulcus (Figs. 4, 5). This internal attachment of the anterior tentorial arms accounts for the anterior tentorial pits being absent externally along the epistomal sulcus.

Labrum.—The labrum of *Lymantria dispar*, as in other insects, is sometimes termed upper lip. It is a broad plate attached to the ventral margin of the clypeus by a membraneous structure (Fig. 2). The labrum overlies the mandibles, and its posterior surface is termed the epipharynx which has taste sensing papillae (Fig. 6). On the lateral angles of the labrum there is a pair of tormae (Fig. 7) which are sclerotized rods. The tormae serve as sites for labial muscle insertion.

The labial muscles, according to Snodgrass (1928, 1932, and 1935), identify the frontal sclerite in all insects with the exception of Diptera in which they have their origin on the clypeus. In larval Lepidoptera the labial muscles arise on a medial ridge behind the triangular part of the frons and the so-called frons in lepidopterous larvae is really the clypeus. This statement adds additional credence to the possibility of the antennal segment being reduced to an inconspicuous structure.

Mandibles.—The mandibles (Figs. 8, 9, and 10) are a pair of strongly sclerotized jaws, situated on each side of the mouth immediately behind the labrum. They represent the basal segment or coxopodite of the typical arthropod limb (Cramptom, 1921). The mandibles of *Lymantria dispar*

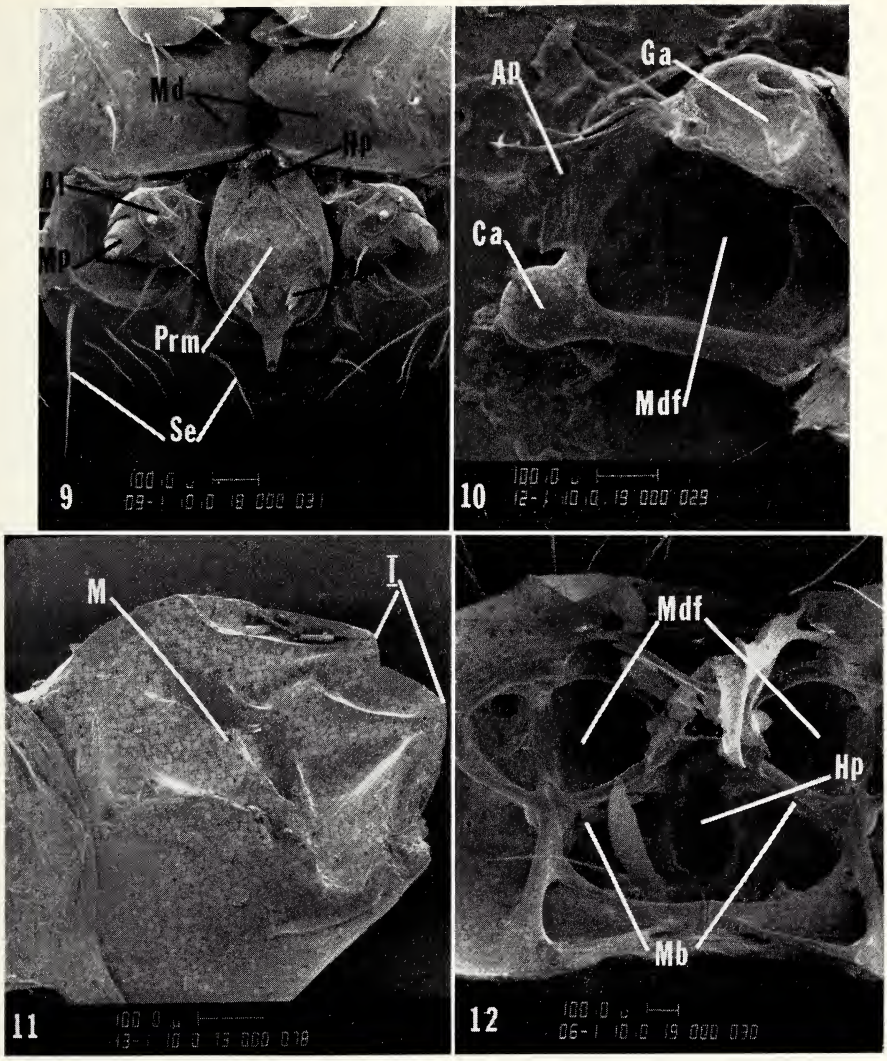

PLATE 3

Fig. 9. Ventral view of the mouth parts of *Lymantria dispar*. Al, accessory lobe; Hp, hypopharynx; Md, mandible; Mp, maxillary palpus; Prm, prementum; Se, setae. 90×.

Fig. 10. Mandible and mandibular articulations of the fourth instar of *Lymantria dispar*. Ap, apodeme; Ca, condyle; Ga, ginglymus; Mdf, mandibular fossa. 120×.

Fig. 11. Mandibular grinding surface of the fourth instar of *Lymantria dispar*. I, incisor; M, molar. 130×.

Fig. 12. Internal view of the mouth parts of a cast head capsule of the fourth instar of *Lymantria dispar*. Hp, hypopharynx; Mb, membrane; Mdf, mandibular fossa. 60×.

in this study were found to be very powerful and the typical chewing type present in most larval insects. They had an incisor area and a molar area (Fig. 11). The mandibles articulated with the pleurostomal margin of the cranium. Anteriorly they were articulated by means of a ginglymus or groove (Fig. 10) which inserts into a convex process of the head, and posteriorly by means of a condyle (Fig. 10) which inserts into a socket at the lower margin of the gena. These two types of articulations allow great movement of the mandibles, which in turn permits consumption of large quantities of food.

Each mandible is moved medially by means of a powerful abductor muscle and opened by a smaller abductor muscle. The abductor observed in this study was a very large muscle originating on the dorsal and posterior walls of the cranium and inserted on a large apodeme at the inter angle of the mandibular base (Fig. 10). The smaller abductor muscle originated on the lateral wall of the cranium and inserted on a small apodeme attached to the outer margin of the mandibular base.

Maxillolabial-hypopharyngeal Complex.—This term was used by Snodgrass (1935) to describe the maxillae, labium and hypopharynx of caterpillars and hymenopterous larvae. However, in a later publication by Snodgrass (1967), in which a segment was devoted to the structure and physiology of the caterpillar, he did not refer to the term maxillolabial-hypopharyngeal complex when describing the head capsule of the tent caterpillar. Other workers Das (1937), Kramer (1955), Ferris (1943), and Cook (1943, 1944) have described heads of various types of insect larvae, but they did not combine the maxilla, labium and hypopharynx into a single complex.

In the case of *Lymantria dispar* the author feels that the term maxillolabial-hypopharyngeal complex deserves credence. In this study it was seen that the entire under lip complex moved as a single unit and was structurally designed to do so. The complex was separated from the postgenal regions by an articulating membrane (which can be viewed internally). This membrane extended completely around the complex with the exception of the hypopharyngeal region (Fig. 12). The complex was clearly free to articulate with the gena and hypostoma regions (Fig. 13) and was braced internally with an endoskeleton that provided support for single unit movement (Fig. 12). Furthermore, there were no fixed points of articulation between the complex and the head capsule proper with the exception of the articulating membrane.

This fact led to the conclusion that any muscle or muscles having an origin outside of the complex would tend to move the entire structure. Muscles having their insertion and origin inside the complex would provide for individual movement of the structural components. This individual

movement was most apparent among the maxillary palpus and the hypopharynx.

Structurally the maxillolabial-hypopharyngeal complex can be subdivided into elemental parts. The elemental parts of the complex vary in degree of individual function from none at all to moderately active. The stipes, cardo and postmentum are nonfunctional except as part of the whole complex, while the maxillary palpus and hypopharyngeal lobe are independently active.

The maxilla was made up of a proximal subdivision—the cardo, a distal subdivision—the stipes, and the maxillary palpus (Fig. 14). The maxillary palpus is an extension of the stipes and appears to be bi-lobed distally. However, this was not the case because the medial structure was found to be an accessory lobe (Fig. 8 and 14) and the marginal structure was the distal two segments of the maxillary palpus. The maxillary palpus was connected to the stipes by a membrane which is shown collapsed in (Fig. 14) and somewhat inflated in (Fig. 8). In reality it appeared more like that pictured in (Fig. 8). This membrane allows for articulation of the maxillary palpus and the accessory lobe which functions as sensory and feeding organs.

The stipes and cardo have no articulation. They are separated from the labium by a strong internal ridge (Fig. 14) used as a site for insertion of stipital muscles (Snodgrass, 1935). In the case of *Lymantria dispar* this ridge serves as the site of insertion for the maxillary palpus muscles. A similar invagination (Fig. 14) separates the cardo from the stipes. However, it did not serve as a site for muscle insertion.

The labium is made up of the postmentum, prementum and hypopharynx. As indicated in Fig. 13 the postmentum showed no fusion with the postgena or hypostomal bridge and appeared as a single structure until formulating a membraneous articulation with the prementum (Fig. 8). The postmentum in insect larvae may form a single plate or may be entirely membraneous (Das, 1937).

Premento-hypopharyngeal lobe.—The prementum along with the hypopharynx forms what Snodgrass (1935) termed the premento-hypopharynx lobe. This term in the case of *Lymantria dispar* is proper. The prementum, which had as its components the labial palpi and the spinneret, combined with the hypopharynx to function as a single unit—the premento-hypopharyngeal lobe. The premento-hypopharyngeal lobe articulated with the postmentum by a membraneous structure (Figs. 14 and 15) which allows for movement back and forth in an anterior–posterior direction. The movement in an anterior–posterior direction may be established because the mouth parts are hypognathous (Fig. 16).

The spined portion of the premento-hypopharyngeal lobe is the hypopharynx (Figs. 9 and 14). The spines on the hypopharynx help to move

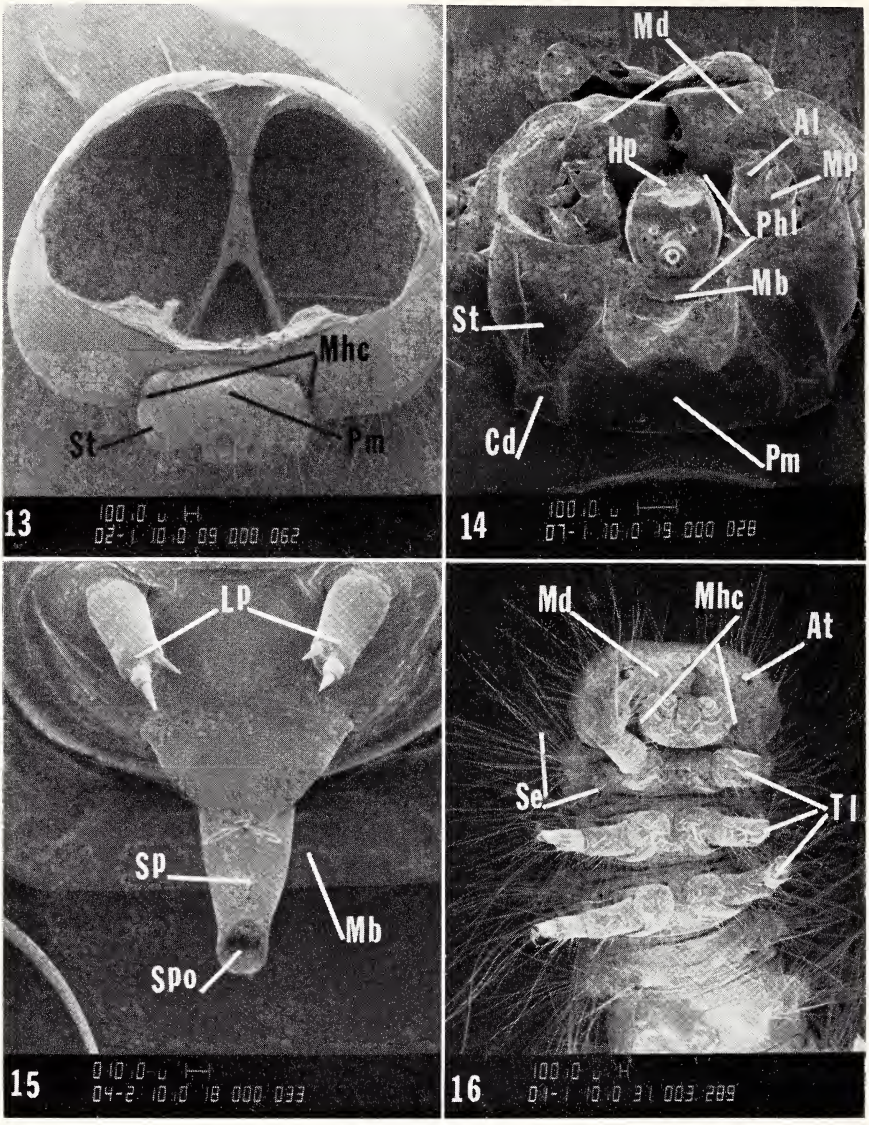

PLATE 4

Fig. 13. Posterior view of the cast head capsule of the fourth instar of *Lymantria dispar*. Mhc, maxillolabial-hypopharyngeal complex; Pm, postmentum; St, stipes. 20×.

Fig. 14. Ventro-posterior view of the maxillolabial-hypopharyngeal complex of the fourth instar of *Lymantria dispar*. Al, accessory lobe; Cd, cardo; Hp, hypopharynx; Mb, membrane; Md, mandible; Mp, maxillary palpus; Phl, prementohypopharyngeal lobe; Pm, postmentum; St, stipes. 70×.

Fig. 15. High power view of the spinneret and labial palpi of the fourth instar of *Lymantria dispar*. Lp, labial palpi, Mb, membrane; Sp, spinneret, Spo, spinneret orifice. 400×.

food from the incisor area to the molar area of the mandibles, and then on into the bucco-pharyngeal region of the stomadaeum. This movement was accounted for by muscles that were found to be inserted on the base of the premento-hypopharyngeal lobe and originated on the tentorium.

The prementum bears distally the spinneret and the labial palpi (Figs. 9, 15). The arms of the prementum extend anteriorly and adnate with the hypopharynx (Fig. 9). The prementum in some caterpillars may be entirely membraneous, but *Lymantria dispar* had a completely sclerotized prementum.

While the labial palpi of *Lymantria dispar* are reduced to form a minor sensory function, the spinning apparatus is just the contrary. The spinneret was seen as a hollow spine having at its exterior the orifice of the silk duct (Fig. 15). The silk duct internally bifurcated into two branches (Fig. 19) which led to the two silk glands located in the abdominal region of the caterpillar (Forbush and Fernald, 1895). These two silk glands later become the salivary glands of the adult (Gray, 1931). The silk glands have the capability of producing a large quantity of silk over a short period of time. However, in the last instar stage they are vestigial (Fig. 17).

At the base of the hypopharynx is a musculated cavity, the salivarium, into which the silk ducts open. In some insects it becomes a salivary pump, especially in sucking forms in which it serves to inject saliva into tissues of the hosts (Roeder, 1953). In Lepidopteran and Trichopteran larvae the salivarium forms a silk press. The silk press squeezes the two strands of silk that are formed by the two silk glands into a single strand by muscular action. While Wigglesworth (1939) stated that the two cylindrical strands are compressed into a flattened ribbon, no evidence of a flattened ribbon appearance existed in *Lymantria dispar* (Fig. 18).

The silk component consists of a highly crystalline control fiber (silk fibroin) surrounded by an amorphous coat of silk gelatine (sericine) (Roeder, 1953). The fibroin makes up seventy to seventy-five percent of the silk strand, and it is a tough elastic protein made up chiefly of glycine, alanine, and tyrosine (Wigglesworth, 1939). The outer coat made up of sericine is water soluble and apparently does not play a major role in solidification since silk will solidify under water. The solidification, however, in either case is virtually instantaneous with silk formation.

In many larvae of Lepidoptera the silk is used to form a cocoon, but the larva of *Lymantria dispar* also use their silk as a mechanism for dispersal.

Parietals.—The parietals constituted the lateral areas of the cranium be-

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Fig. 16. Ventral view of the thorax and head capsule of the fourth instar of *Lymantria dispar*. At, antenna; Md, mandible; Mhc, maxillolabial-hypopharyngeal complex; Se, setae; Tl, thoracic legs. 10×.

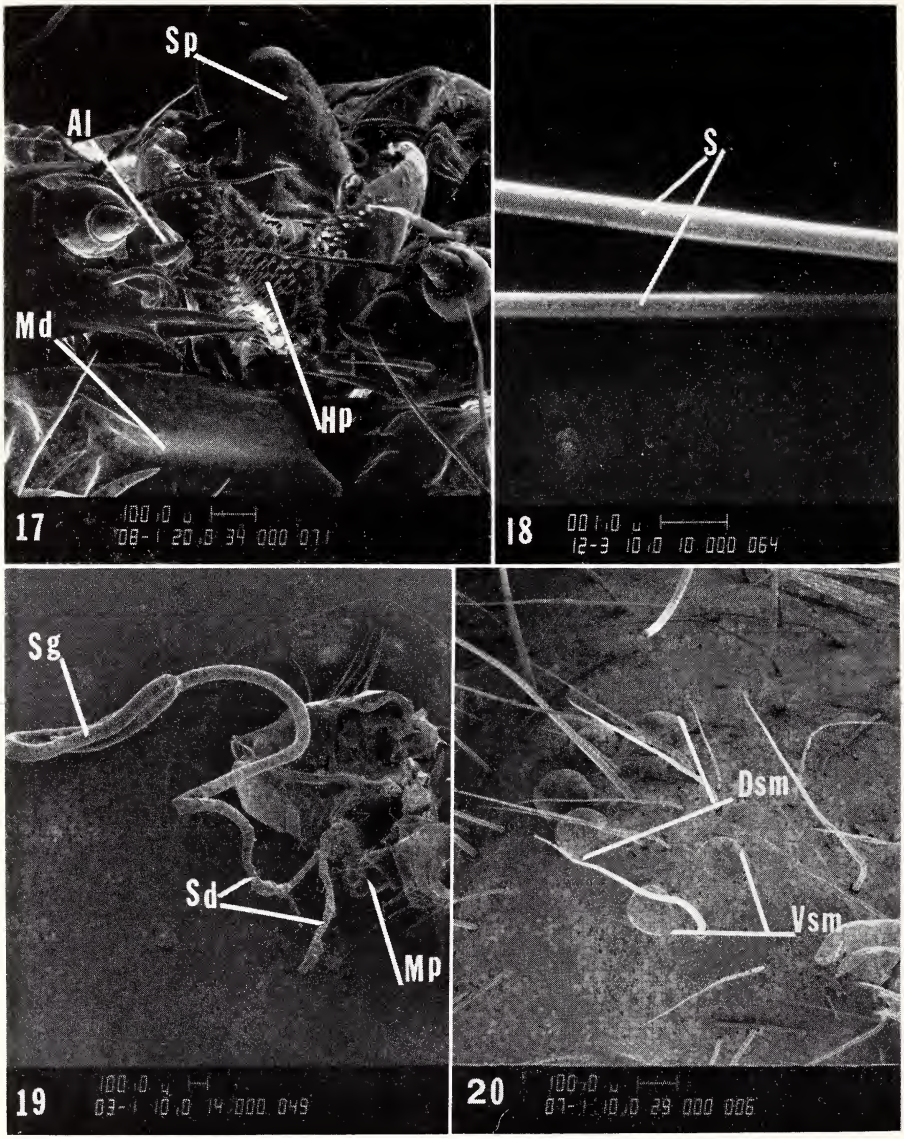

PLATE 5

Fig. 17. View of the mouth area of the sixth instar of *Lymantria dispar* showing vestigial spinneret. Al, accessory lobe; Hp, hypopharynx; Md, mandible; Sp, spinneret. 80×.

Fig. 18. High power view of silk strands spun by the first instar of *Lymantria dispar*. S, silk. 12,000×.

Fig. 19. View showing silk duct and silk gland of the fourth instar of *Lymantria dispar*. Silk gland is located in abdominal cavity. Mp, maxillary palpus; Sd, silk duct; Sg, silk gland. 30×.

tween the frontal and occipital areas, separated dorsally by the coronal sulcus (Fig. 4). The stemmata were located on each parietal as well as numerous setae (Fig. 1). The parietals did not include the antennae, since the antennae were shown earlier to be a part of the antennal segment which has undergone reduction to the extent of being inconspicuous.

The stemmata were located just above the mouth parts on each parietal and had a circular configuration (Fig. 20). They appeared individually as a group of six and could be separated into three pairs. The two pairs of stemmata that were located close to one another (Fig. 20) represented the dorsal stemmata, while the single pair that was spaced further apart represented the ventral pair. Each stemma had a structure somewhat like a single ommatidium of a compound eye. It is made up of a cornal lens (Fig. 21) and a crystalline cone that overlies a rhabdome-like structure (Detheir, 1942). The principal function of the stemmata according to Patton (1973) is probably that of a perception of light and dark. However, Wigglesworth (1939) took a firmer view by stating: "There is no doubt that in all cases the stemmata are organs for the perception of light; and in some insects, in spite of their very simple structure they also subserve colour vision and a rudimentary perception of form." Each stemma receives light from the area at which it is directed and, since the fields of adjacent stemmata do not overlap, a caterpillar with six stemmata on each parietal will perceive twelve points of light from different parts of the visual field (Chapman 1969). In this manner the caterpillar perceives a course pattern which is improved by side to side movements of the head, enabling it to examine a larger field.

The parietals extend dorsally to the cornal sulcus and posteriorly to the occipital region (Fig. 4), rounding out the dorsal surface of the head capsule. Externally, the dorsal parietals contained no structures except tactile setae, but internally, they were the site of muscle origin.

The cornal sulcus of *Lymantria dispar* is not synonymous with the ecdysial cleavage line as proposed by Chapman, because the head capsule is cast intact and not cleaved. Furthermore, it was found to be invaginated by a thin membraneous structure (Fig. 5) to connect with the tentorium giving credence to the term sulcus instead of suture.

The occipit formed a dorsal arch extending halfway down each parietal (Figs. 3 and 4). It did not extend down to or include the post gena.

The postoccipit was separated from the occipit by the postoccipital suture (Fig. 3), and it completely circumvented the occipital foramen

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Fig. 20. View showing the stemmata located just above each mandible on the parietals. The stemmata are grouped in pairs. Dsm, dorsal pairs of stemmata; Vsm, ventral pair of stemmata. 70×.

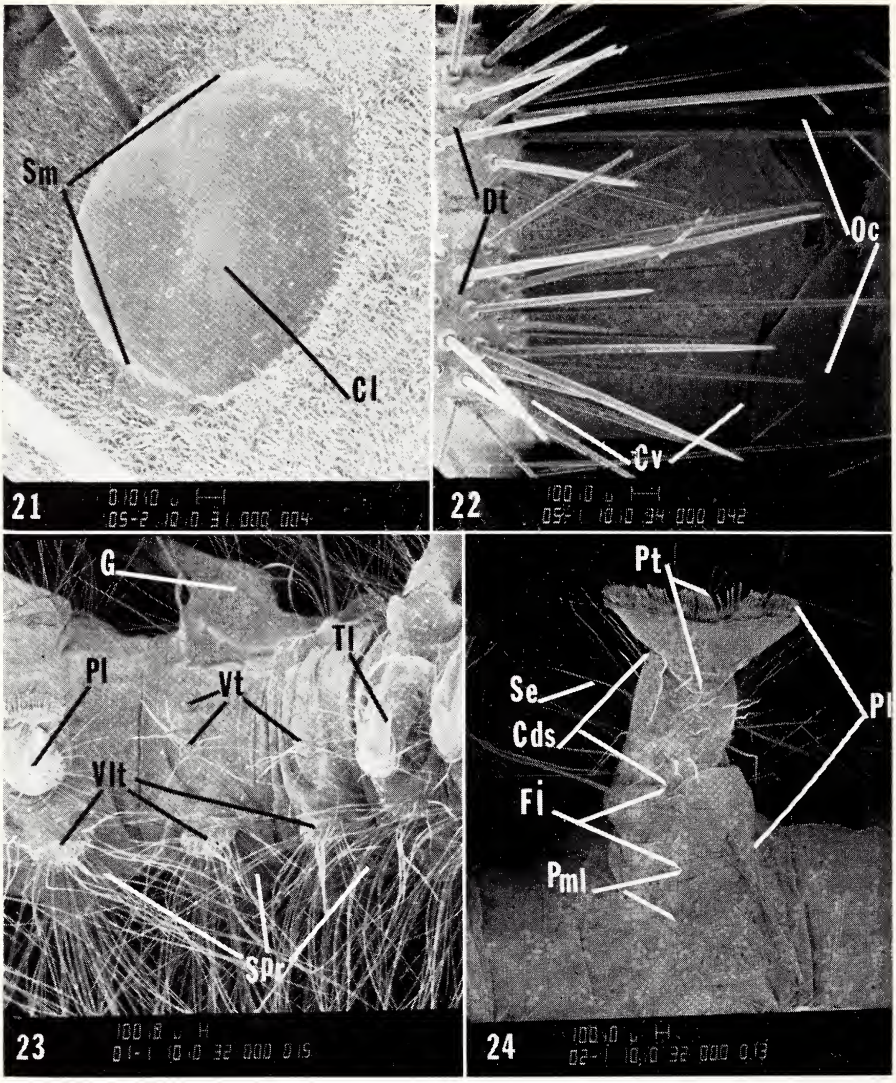

PLATE 6

Fig. 21. High power view of a stemma of the fourth instar of *Lymantria dispar*. Cl, coronal lens; Sm, stemma. 500×.

Fig. 22. View showing the cervex between the head capsule and first thoracic segment of the fourth instar of *Lymantria dispar*. Cv, cervex; Dt, dorsal tubercle; Oc, occiput. 50×.

Fig. 23. Ventro-lateral view of the segments between the thoracic legs and the prolegs of the fourth instar of *Lymantria dispar*. G, ground; Pl, prolegs; Tl, thoracic legs; Vlt, ventro-lateral tubercle; Vt, ventral tubercles. 10×.

Fig. 24. Ventral view of an abdominal proleg of the fourth instar of *Lymantria dispar*. Cds, cylindrical section; Fi, flexible integuments; Pl, proleg; Pml, prominent lobe; Pt, planta; Se, seta. 20×.

(Fig. 4). The postoccipit was also the site for attachment of the cervical membrane (Fig. 22).

Thoracic and Abdominal Anatomy

Segmentation.—Combined, the thorax and abdomen of *Lymantria dispar* consisted of twelve segments. The first three segments constituted the thorax and segments four to twelve the abdomen. The thoracic segments (one–three) were subdivided into the prothorax, mesothorax, and the metathorax, respectively. Each segment of the thorax had a pair of legs (Fig. 16) and encircling hair tufts but only the prothoracic segment had a pair of spiracles located posterior to the dorsal-lateral hair tufts. Segments four and five were void of legs, but they had encircling hair tufts and paired spiracles (Fig. 23). Segments six, seven, eight, and nine had prolegs (Fig. 24) on each segment as well as hair tufts and paired spiracles. Segments nine and ten had two conspicuous glands located on the dorsum between the dorsal hair tufts (Fig. 25). Segments nine, ten, and eleven had encircling hair tufts and paired spiracles. Segment twelve, the anal segment, was void of spiracles but did possess a pair of legs synonymous with the prolegs. The hair tufts on segment twelve were arranged in a semicircle around the dorsum.

The area encircling the junction of each segment is flexible and consists of an intersegmental membrane. This intersegmental membrane was seen to be attached to the posterior fold (Fig. 25) and the intersegmental groove. Each intersegmental groove was attached to a principal longitudinal band of somatic muscles. These muscles are innervated mainly by the preceding segment (Forbes, 1914). Upon innervation the muscles contract pulling the segments anterior in a rhythmic fashion. As the rhythmic wave of contraction reaches a segment the intersegmental membrane is flexed and the posterior fold (Fig. 25) slides over the anterior portion of the succeeding segment. This arrangement allows the muscles of each segment to draw the following segment forward. By having this type of segmentation, the larva can bend the body freely in any direction, and shorten it by a lengthwise contraction of the segments.

Cervex.—The cervex of *Lymantria dispar* (Fig. 22) was seen as a rather elongated membrane when extended. It attached the head capsule to the first thoracic segment and allowed articulation of the head independently of the thorax. The larvae of *Lymantria dispar* rarely extends the cervex, as indicated in Fig. 22, except during molting. The cervex appeared to be the area of weakness that allows exit from the old cuticle, as evident from a cast cuticle of the thorax and abdomen (Fig. 26).

Hair tufts.—The larva of *Lymantria dispar* is covered with hair tufts. These hair tufts completely circumvent each segment void of legs, and

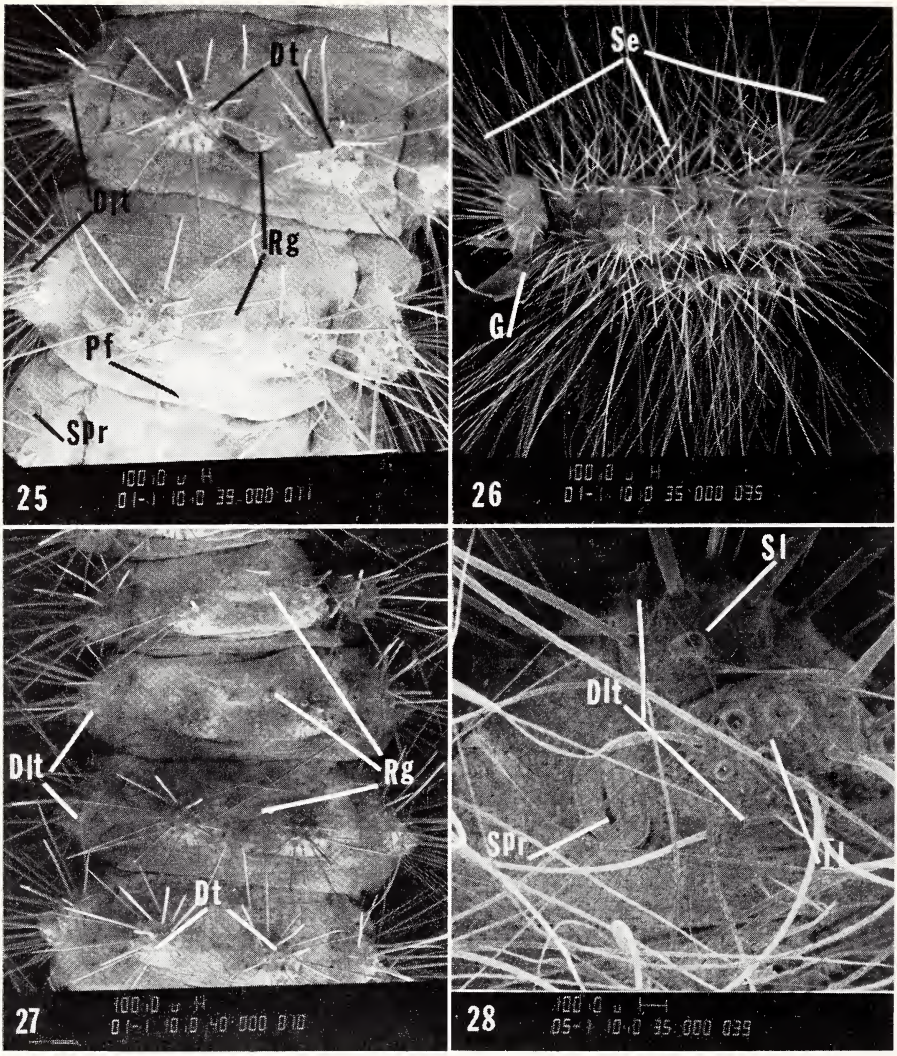

PLATE 7

Fig. 25. Dorsal view of the ninth and tenth abdominal segments of the fourth instar of *Lymantria dispar*. Dlt, dorso-lateral tubercles; Dt, dorsal tubercles; Pf, posterior fold; Rg, repugnatory glands; Spr, spiracle. 10×.

Fig. 26. Cast abdominal cuticle of the third instar of *Lymantria dispar*. G, ground; Se, setae. 10×.

Fig. 27. Dorsal view of the third, fourth, and fifth abdominal segments of the fourth instar of *Lymantria dispar*. Dlt, dorso-lateral tubercles; Dt, dorsal tubercles; Rg, repugnatory gland. 10×.

Fig. 28. View showing the two lobes of the dorso-lateral tubercle of the fourth instar of *Lymantria dispar*. Dlt, dorso-lateral tubercle; Il, inferior lobe; Sl, superior lobe; Spr, spiracle. 50×.

they encircle dorsally and laterally segments that possess legs. The hair tufts were found to be twelve in number on segments four, five, ten, and eleven which are without legs, six in number on the thoracic segments (one to three) which have legs and eight in number on segments six, seven, eight, and nine which have prolegs. Hair tufts were also located on the twelfth segment. Six hair tufts were seen arranged in a semicircle around the dorsum, while two smaller ones were located on the ventral side anterior to the anal legs. Each hair tuft was similar in anatomical appearance in that it was made up of the tubercle, setal socket, and seta. However, the tubercles and length of seta did vary in appearance.

The tubercle forms the basal portion of the hair tuft. It is an outgrowth of the integument which gives rise to numerous setal sockets. Each tubercle so named gives rise to a corresponding name for the hair tuft. Thus the pair of dorso-lateral tubercles gives rise to the pair of dorso-lateral hair tufts. As were the hair tufts, the tubercles located ventrally were much smaller than tubercles located on the dorso-lateral region (Fig. 23). The tubercles may be classified in accord to their location on the insect's body. The dorsal tubercles were paired (Figs. 22 and 25), and they took on characteristic hues. The first five segments had dorsal tubercles that were blue in color, while the remaining pairs of dorsal tubercles were reddish-brown. The pair of tubercles located lateral to the dorsal pair were bi-lobed (Fig. 27). The entire tubercle is termed the dorso-lateral tubercle, while the lobe toward the dorsum is termed the superior lobe and the lobe toward the ventral is termed the inferior lobe (Fig. 28). These two lobes, along with the setae, constituted the dorso-lateral hair tuft. The tubercle located ventral to the dorso-lateral tubercle was the ventro-lateral tubercle (Fig. 29). The first ventral tubercle was located just below and posterior to the ventro-lateral tubercle (Fig. 23 and 29). The first ventral tubercle was present on segments one to eleven while the second and third ventral tubercles were conspicuous only on segments four, five, ten, and eleven which were void of legs. The dorsal, dorso-lateral, ventro-lateral, and ventral pairs of tubercles took on the same pattern on all segments except segment one and the anal segment (twelve). On the first segment, the dorsal tubercles were larger, and on the anal segment they were arranged in a semicircle of six around the dorsum. The second and third pairs of ventral tubercles were absent on all segments possessing legs, with the exception of the anal segment which has a pair of ventral tubercles located just anterior to the pair of anal legs.

The cellular make-up of the tubercle is different from the surrounding integument because of setal socket and setal formation. Structures that form the seta and setal socket are unicellular. The epidermal cell that forms a seta is termed the trichogenous cell. Closely associated with the trichogenous cell there is usually a second cell that forms the setal socket—

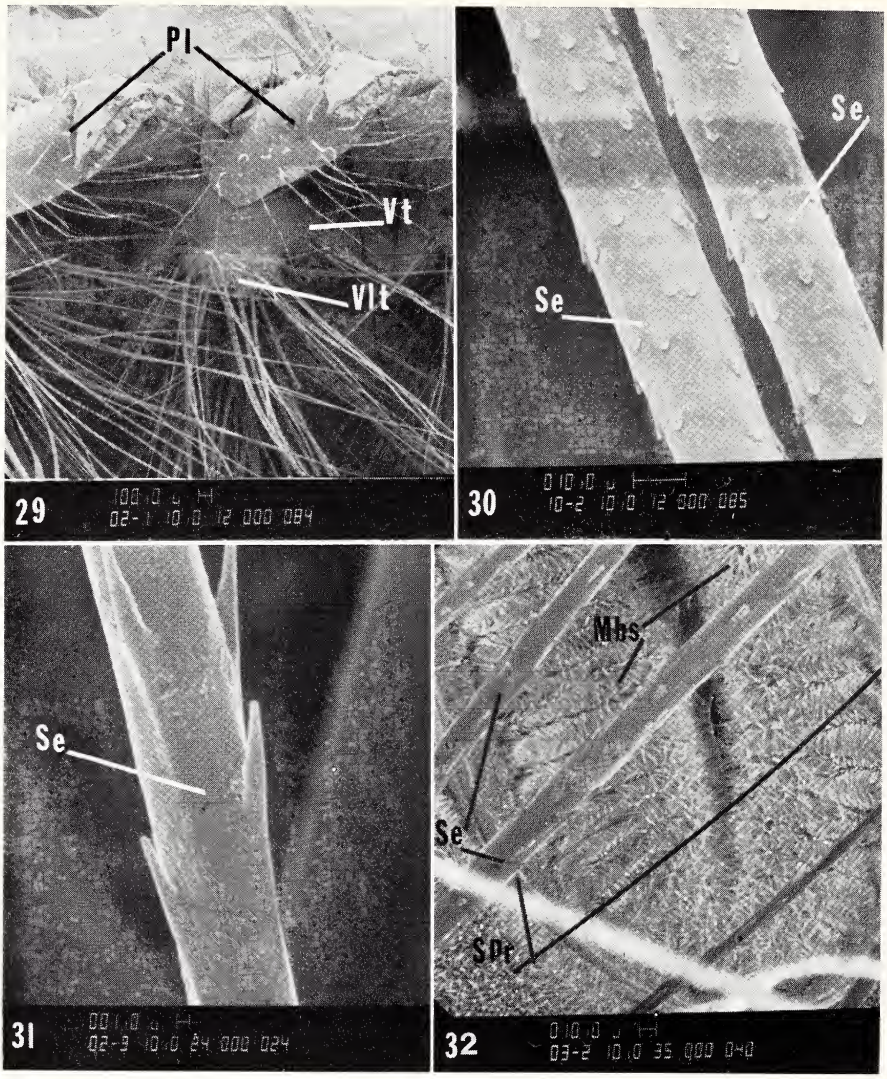

PLATE 8

Fig. 29. Ventro-lateral view of the fourth instar of *Lymantria dispar* showing prolegs and ventral tubercles. Pl, prolegs; Vlt, ventro-lateral tubercles; Vt, ventral tubercle. 20×.

Fig. 30. High power view of lateral projecting setae of the fourth instar of *Lymantria dispar* showing scale like barbs. 1,000×.

Fig. 31. High power view of a lateral projecting seta of the fourth instar of *Lymantria dispar* showing sharp barbs. Se, seta. 2,000×

Fig. 32. View of lateral projecting setae and spiracle aperture of the fourth instar of *Lymantria dispar*. Mbs, matted brushes; Se, setae; Spr, spiracle. 300×.

the tromogen cell. The setal forming process of the trichogenous cell, during the period of setal growth, penetrates the tromogen like a finger thrust through a ring (Haffer, 1921; Wigglesworth, 1933).

Setae.—Most setae on the larva of *Lymantria dispar* arose from the tubercles, but the setae were by no means restricted to the area of the tubercles. In fact, setae could be located on essentially every component structure of the insect—especially the cranium, mouth parts, and legs (Figs. 1, 9, 16 and 24). Setae that arose from the dorsal tubercles and from non-tubercular areas were characteristically short and stout, when compared to setae arising from the dorso-lateral and ventro-lateral tubercles (Figs. 1, 24 and 26). The setae seen arising from the inferior lobe of the dorso-lateral tubercle and the ventro-lateral tubercle were longer (Fig. 28) and most often barbed (Figs. 30, 31 and 32). Laterally projected setae were most apt to be barbed, while dorsally and ventrally projected setae were normally non-barbed. Also setae arising from the integument at sites other than tubercles were normally non-barbed as well.

The barbed appearance was not uniform with all setae. It ranged from a sharp long barb (Fig. 31) to an intermediate form (Fig. 32), and then to a scale like barb (Fig. 30).

The setae of *Lymantria dispar* play an important role as tactile organs, especially the long setae that project from the two large dorsal tubercles on the first thoracic segment. In setae that are used for sensory purposes, there are sensory nerve cells located in or just beneath the epidermis. These cells are connected to the setae by a distal nerve process (Snodgrass, 1935). Thus, when the nerve cells are innervated, they become a setal sense organ.

Thoracic legs.—The pro-, meso-, and meta-thorax each have paired legs (Fig. 16). These legs are more instrumental in feeding than they are in locomotion. They are well endowed with setae that serve a tactile function. Although all three pairs of thoracic legs are identical in structure, the first pair is used almost exclusively to manipulate food toward the mouth parts, and to climb up silk strands.

The basal segment of the leg is termed the coxa (Fig. 33). It is attached to the body by an articulating membrane, the coxal corium, which surrounds its base. However, in *Lymantria dispar* as in most caterpillars, this membrane was not extensive because most of the articulation occurred distal to the coxa.

In most all insects the segment of the leg located just distal to the coxa, the trochanter, is small and inconspicuous. The trochanter of *Lymantria dispar* formed a membraneous articulation with the coxa but was fixed at its distal articulation with the femur (Fig. 33).

The femur (Fig. 33) is the longest segment of the thoracic leg and,

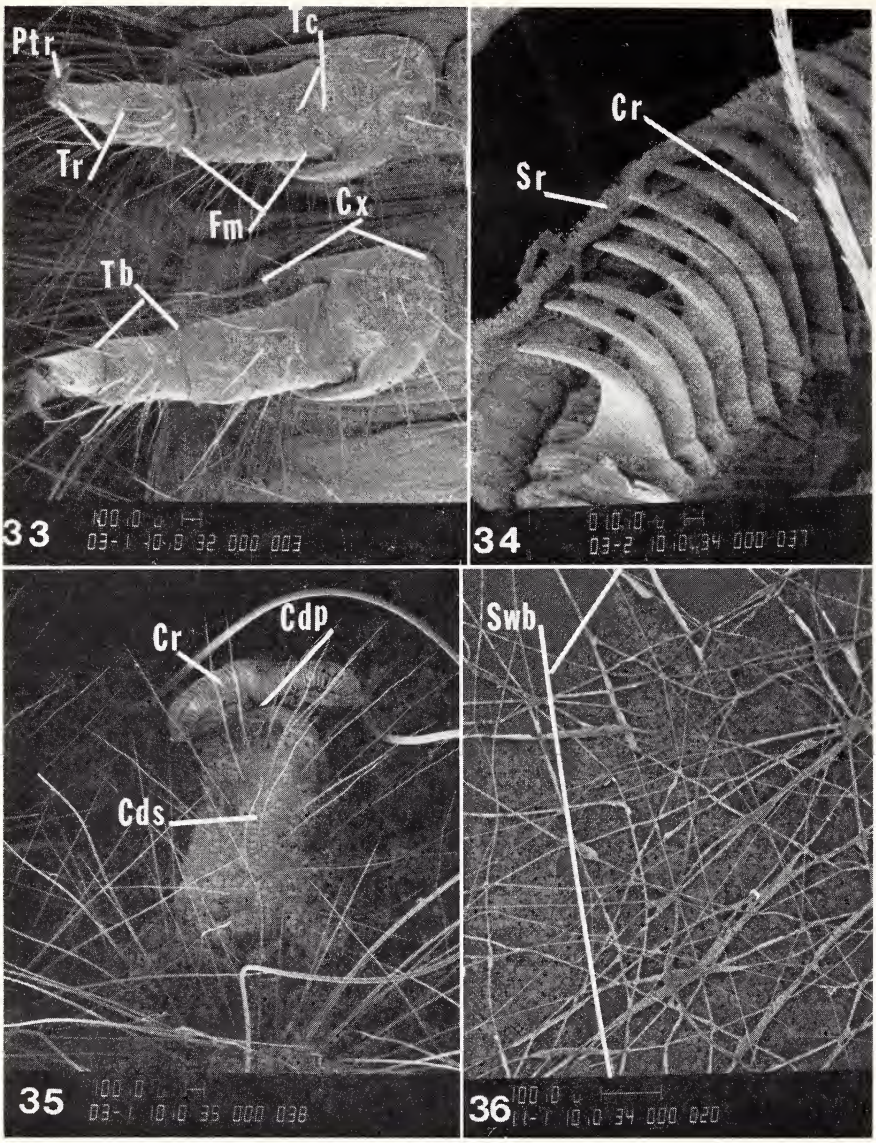

PLATE 9

Fig. 33. Ventral view of the thoracic legs of the fourth instar of *Lymantria dispar*. Cx, coxa; Fm, femur; Ptr, pretarsus; Tb, tibia; Tc, trochanter; Tr, tarsus. 30×.

Fig. 34. Distal end of the proleg planta of the fourth instar of *Lymantria dispar* showing crochets and sensory ridge. Cr, crochets; Sr, sensory ridge. 300×.

Fig. 35. Lateral view of proleg of the fourth instar of *Lymantria dispar*. Cds, cylindrical section; Cdp, central depression; Cr, crochets. 30×.

Fig. 36. Silk webbing spun by the later instars of *Lymantria dispar* to aid in clinging to a surface by the crochets. Swb, silk webbing. 110×.

therefore, accounts for a substantial amount of leg movement. The femur articulated distally with the tibia by a membrane.

The tibia was a much shorter segment than the femur, but it could be articulated back toward the femur giving it greater flexibility.

The tarsus is the segment distal to the tibia and has only one segment in the caterpillar larvae, however, in adult insects it normally has several segments.

The terminal segment of the thoracic leg was the pretarsus which was no more than a simple claw (Fig. 33).

Prolegs.—The larvae of *Lymantria dispar* have four pairs of prolegs located on segments six, seven, eight, and nine. Each pair of prolegs is anatomically the same. They also have the same function. Structurally the prolegs consist of three parts. The basal part was seen as a ring of flexible integument which articulated with a prominate lobe of the body (Fig. 24). The cylindrical section was the intermediate part. It was the longest part of the proleg and normally had a number of setae arranged around its circumference (Fig. 24). The distal part was the planta which had crochets arranged along its outer edge (Fig. 34). Just proximal to the crochets was a line of sensory projections (Fig. 34).

The prominate lobe was a raised portion of the integument wall (Fig. 24). It is nonfunctional from a mechanical view, but along its base was an apodeme which served as a site for muscle attachment. The prominate lobe also provided a base which aligned the other leg parts vertically with the substrate.

The flexible integument (Fig. 24) articulates with the prominate lobe and allows movement of parts distally. The flexible integument had no muscles attached and serves the sole function of allowing movement mainly in anterior–posterior and medial direction. It does not allow for much lateral movement, nor were there muscles located internally that would accommodate this lateral movement.

The cylindrical section (Fig. 24) was the longest part of the proleg. It took on the appearance of a sclerotized tube. The cylindrical section internally was the main site of muscle insertion—thus providing movement in an anterior, posterior, and medial direction. The cylindrical section articulated distally with the planta by a membraneous structure.

The planta is the most functional part of the proleg, and it includes as its components the crochets, central depression, and the sensory ridge (Figs. 34 and 35). The planta is the part of the proleg that makes contact with the substrate, and it provides a means of securing the larva with great adherence. The planta secures the larva to the substrate surface by either suction tension or grasp of the crochets.

On smooth surfaces the larva presses the sole of the planta out flat with the claw turned upward, and apparently a tension of the plantar muscles

provides a suction by which the caterpillar maintains a foothold. This suction method will sustain young larvae in an upside down position, but as the larvae increase in size, they cannot develop enough suction to support their body weight. A combination of suction and grasping with the crochets may be employed to maintain larger larvae in an upside down position, or grasping by the crochets alone may be employed providing the surface is suitable.

To aid in clinging upside down on smooth surfaces the larger larvae must spin silk. The silk webbing is not spun in any characteristic pattern (Fig. 36) and serves the sole function as a device by which the larvae attach their crochets.

The crochets were found to be aligned along the distal margin of the planta (Figs. 33 and 34). They were curved toward the caterpillar's midline at a 90° angle (Fig. 34), which allows them to be inserted in the webbing so that entanglement will be minimized. The crochets are well coordinated with the rhythmic wave of concentration that progresses along the insect's body. They are innervated to release their grasp simultaneously with the innervation of the muscles of the corresponding segment. How much help in innervation the crochets receive from the sensory ridge is open to speculation. Perhaps the sensory ridge is able to sense the nature of the surface, thus telling whether the surface is appropriate for clinging by use of the crochets.

The larvae can attach themselves to a suitable substrate by the crochets with such intensity that the prolegs will be severed from the prominate lobe if sufficient force is applied.

The anal pair of legs, termed anal proleg, located on the twelfth segment differed slightly from the abdominal prolegs on segment six, seven, eight, and nine. The anal prolegs did not have a distinct prominate lobe and the flexible membrane was reduced. The anal prolegs had a longer cylindrical section (Fig. 37) which articulated distally with the planta. The planta of the anal proleg was synonymous with the plantae of the prolegs on segments six, seven, eight, and nine. The anal prolegs exhibited little individual movement in an anterior, posterior, or medial direction, but they did have compatible planta function with the other segmental prolegs.

Spiracles.—Each abdominal segment of *Lymantria dispar* except the second, third, and anal segments, had paired spiracles. The spiracles on the first segment were located just posterior to the dorso-lateral hair tufts, and on segments four to eleven they were located on each side of the abdomen just anterior and slightly ventral to the dorso-lateral hair tufts (Figs. 23 and 28). The spiracles on all segments had the same anatomical structure. They were oval in appearance and had accessory structures which protruded into the atrium to serve as a filter apparatus. The spiracle filtering apparatus was in the form of two rows of matted brushes pro-

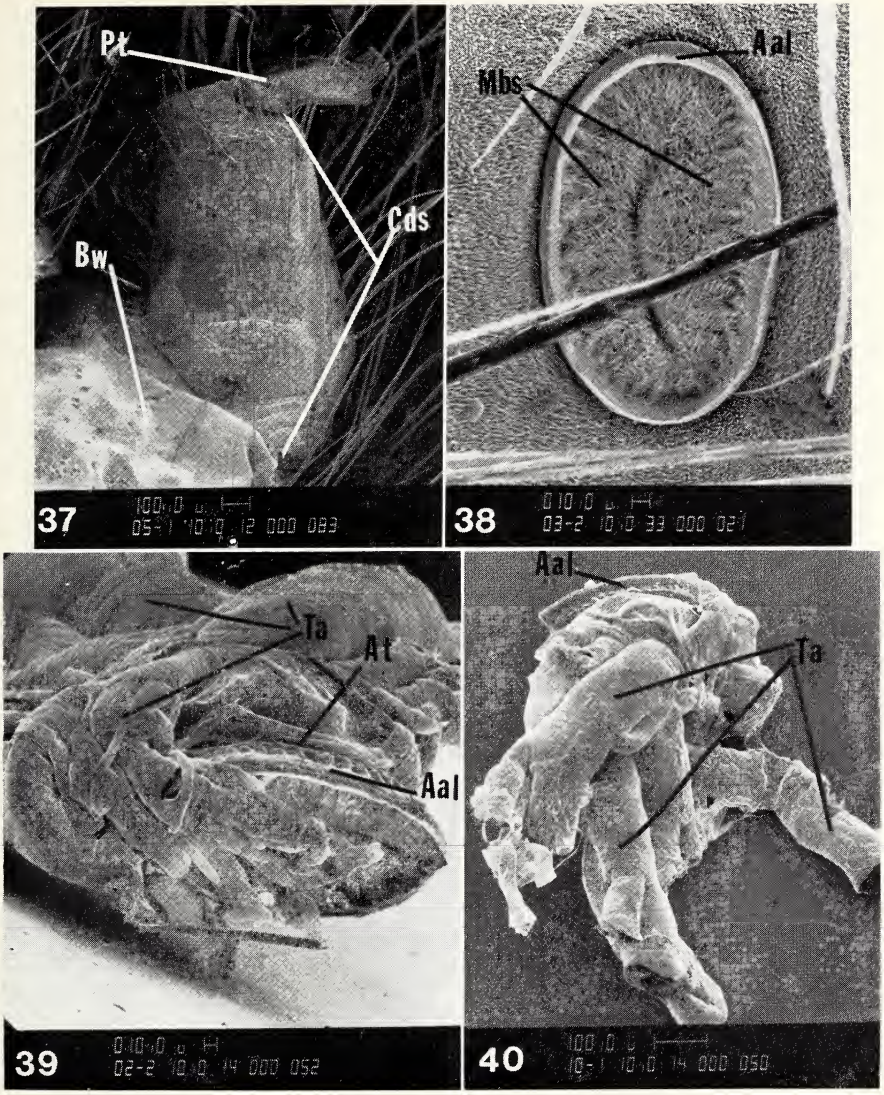

PLATE 10

Fig. 37. View of the anal leg of the fourth instar of *Lymantria dispar* showing a long cylindrical section and the planta which is identical to the plantae of the prolegs. Bw, body wall; Cds, cylindrical section; Pt, planta. 50×.

Fig. 38. External view of the spiracle aperture of the fourth instar of *Lymantria dispar*. Aal, atrial lip; Mbs, matted brushes. 300×.

Fig. 39. Spiracle, with part of the tracheal trunks, dissected from the fourth instar of *Lymantria dispar*. Aal, atrial lip; At, atrium; Ta, trachea. 200×.

Fig. 40. Spiracle, with part of the tracheal trunks, dissected from the fourth instar of *Lymantria dispar*. Aal, atrial lip; Ta, trachea. 100×.

jecting from opposite walls of the atrium (Figs. 32 and 38). The spiracle had its connection with the body wall by the lip of the atrial aperture, therefore, the spiracle was not attached to the body wall via a peritreme (Fig. 38). The spiracular atrium continued for a short distance internal to the filtering apparatus. It terminated at a valve which serves to regulate the flow of oxygen internally and carbon dioxide externally. In this form of spiracle the atrial lip is not moveable and takes no active part in the closing of the spiracle.

Snodgrass (1935) described the mechanism for closing the atrial valve in the larvae of Lepidoptera. He stated that the essential elements of the closing structure are a looped bar in the membraneous valve on which is supported a lever, a concavity in the posterior atrial wall, and a closing muscle. When the closing muscle is innervated it applies force on the lever attached to the looped bar and forces the membraneous valve into the concavity of the posterior atrial wall. Thus closing the juncture between the atrium and the trachea.

The tracheal system of *Lymantria dispar* was found to be quite extensive (Figs. 39 and 40). It is used not only for the assimilation and excretion of oxygen and carbon dioxide, but it is also used to eliminate water. Structurally the tracheal system consists of the trachea which are large tubes running inwards from the spiracle and branch out into smaller tubes (Figs. 39 and 40). The trachea are formed by invaginations of the body wall and are so lined by a cuticular intima which is continuous with the rest of the body wall. A spiral thickening of the cuticular intima runs along each tube. This spiral thickening gives a ringed appearance to the trachea (Fig. 41). The spiral rings are referred to collectively as the taenidia and individually as the taenidium. The taenida prevent the collapse of the trachea if the pressure within is reduced.

Repugnatory Glands.—On the ninth and tenth segments of *Lymantria dispar* a glandular structure was found located between the dorsal hair tufts (Figs. 25 and 42). At this point in time, the author applies the term repugnatory gland to each of these structures because they no doubt serve a repugnatory function. However, there is some evidence that these glands may serve additional functions. In a personal conversation with Charles C. Doane (Research Entomologist for the Connecticut Agriculture Experiment Station, New Haven, Connecticut), he indicated that the so called repugnatory glands may have a pheromone function as well. Doane stated that on occasion a large number of caterpillars could be observed congregating in one spot with no apparent stimulus for this congregation. Therefore, speculation of a pheromone function for these glands would merit some consideration. The glands may serve to enhance the tactile stimulus of the setae. On occasion the larvae of *Lymantria dispar* may be observed arching the anterior portion of their bodies over the area of the glands and

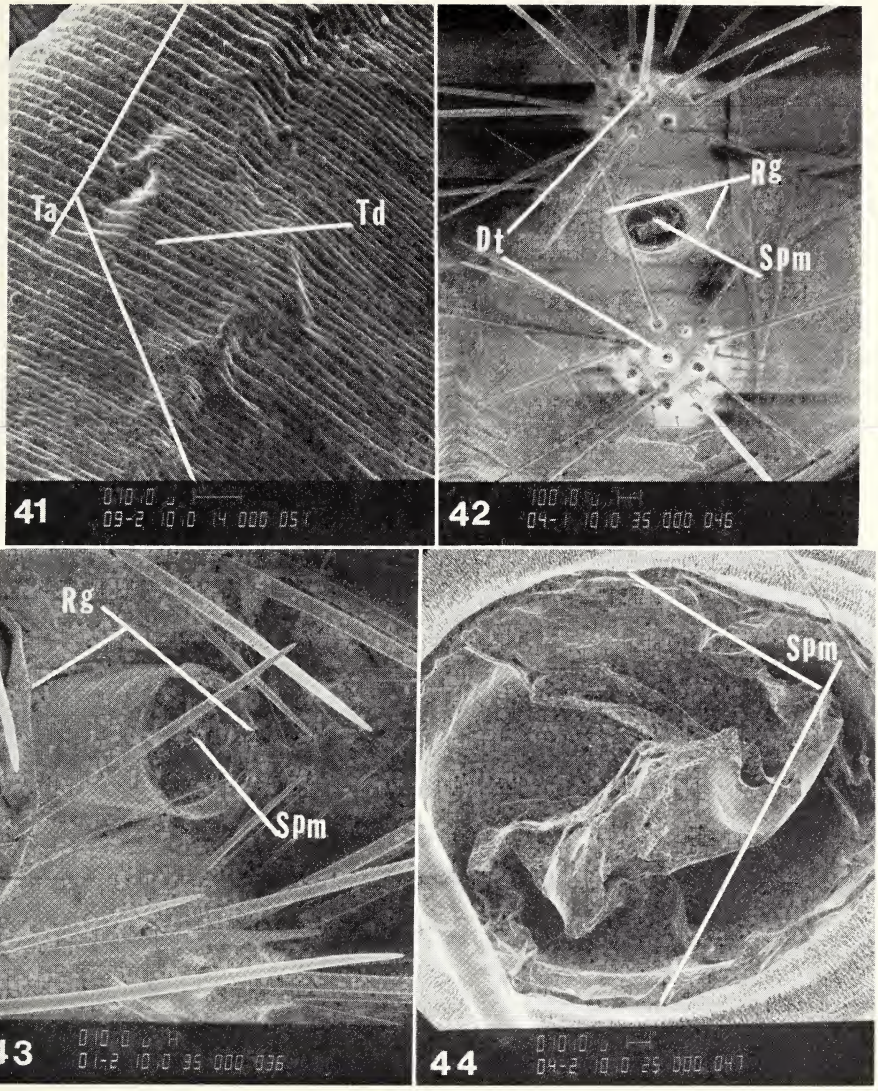

PLATE 11

Fig. 41. High power view of a tracheal trunk of the fourth instar of *Lymantria dispar.* Ta, trachea; Td, taenidium. 900×.

Fig. 42. View showing the repugnatory gland located between the dorsal tubercles on a fourth instar larva of *Lymantria dispar.* Dt, dorsal tubercle; Rg, repugnatory gland; Spm, selectively permeable membrane. 40×.

Fig. 43. Cuticle that has been cast from third instar showing remanents of the repugnatory gland. Rg, repugnatory gland; Spm, selectively permeable membrane. 100×.

Fig. 44. High power view of the selectively permeable membrane of the fourth instar of *Lymantria dispar.* Spm, selectively permeable membrane. 400×.

then commence to rub the setae of the dorsal hair tufts in the glandular secretion. This phenomenon may also provide the tactile setae with a means of laying down a scent trail.

On segments four, five, six, and seven there were paired structures that had the same anatomical appearance as the repugnatory glands on segments nine and ten with the exception that they were much smaller in size (Fig. 27). The function of these structures is apparently the same as the larger glands, although the smaller glands produce much less secretory content.

Structurally the repugnatory glands are a cuticular product. Externally the cuticle was seen to be extended dorsally between the two dorsal hair tufts to form a small tube (Figs. 42 and 43). At the end of this cuticular extension was a selectively permeable membrane (Fig. 44). When the membrane was inflated, it extended out approximately the height of the cuticular extension forming the tube. When it collapsed, a liquid secretion pooled in the pocket that was formed. The repugnatory gland internally was attached to an extensive network of tubes. The tubes seemed to be derivatives of the cuticular intima. Their function is glandular, but in appearance they extended in all directions throughout the abdominal cavity.

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A NEW DIAGNOSTIC CHARACTER IN THE FOREWING OF APOIDEA (HYMENOPTERA)

U. N. Lanham

Abstract.—Lanham, U. N., University of Colorado Museum, Boulder 80309.—The position of the stigma relative to the rest of the venation in the forewing of Apoidea offers a diagnostic character of generic and higher rank. This new character is strongly correlated with the relative sizes of the jugal and vannal lobes of the hind wing.

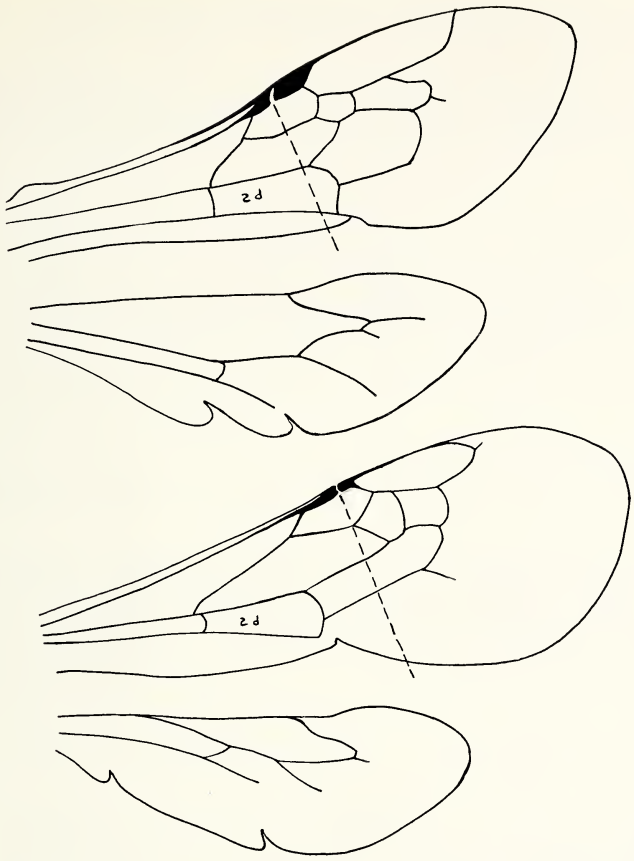
Writing keys for the identification of the genera of bees has always challenged the ingenuity of taxonomists because the males and the parasitic genera lack the pollen-transporting field, whose diversification has played a major role in bee phylogeny. Therefore, any new external character not related to pollen transport is potentially useful.

The character described here concerns the position of the stigma relative to the rest of the venational pattern of the forewing. Two character states can be discerned which are nearly always constant within genera. This has been determined for the 62 genera which occur in Colorado (about 100 genera make up the North American fauna). In character state 1, the stigmal break (the weakly sclerotized area between the prestigma and pterostigma) is said to be "basal"; in state 2, it is "distal."

If the stigmal break is basal, a line perpendicular to the front margin of the wing and projecting from the break to the hind margin of the wing cuts through the second discoidal cell and crosses the margin basad of the postero-lateral corner of that cell. With experience, this relationship can be determined at a glance. For accuracy, an ocular grid should be used, with the apex of a right angle positioned at the stigmal break. The front margin is taken as the sector between the break and the wing base. If the costal vein has been rotated under the subcostal, the latter vein may be taken as the wing margin.

In the distal break, the perpendicular crosses the hind margin distad of the corner of the second discoidal.

The break of the stigma is basal in the genera of andrenids except *Calliopsis,* and in the genera of halictids. It is distal in the megachilids, and all but the most primitive anthophorids. These remarks refer to the genera found in Colorado. It may be that this character will prove of use in classification as well as in practical keys. The genus *Megandrena,* which does not occur in Colorado, is generally conceded to be a primitive andrenid, but its exact position has been a matter of controversy. Unlike the genus *Andrena,* it has the stigmal break distal, as in *Colletes* and in



Above: front and hind wing of *Nomia*; stigmal break basal. Below: front and hind wing of *Anthophora*; stigmal break distal. 2d = second discoidal cell.

some *Calliopsis*, where it is slightly distal, although in others it strikes the corner of the second discoidal cell.

A wing character that has been much used for classification and identification of bees has been the lobing of the posterior margin of the hind wing. The two character states are (1) jugal lobe less than ⅔ as long as the vannal lobe, and (2) jugal lobe more than ⅔ (usually ¾) as long as the vannal lobe. The length of the vannal lobe is taken to be the distance from its tip to the wing base.

It is interesting that there is a strong correlation between the position of the stigmal break and the character states of the jugal lobe of hind wing. In general, a basal break of the stigma means a long jugal lobe. This makes the stigmal character useful because in older bees the hind margin

becomes frayed with use, often so much that the outlines of the lobes can not be made out.

The table sets out the four character states in more detail. The entry +– means intermediate or nearly so. In the family Apidae, *Bombus* and *Psithyrus* are without a jugal lobe, and *Apis* has the hind margin very weakly lobed.

	Stigmal break		jugal/vannal lobe	
	basal	distal	<⅔	>⅔
Colletidae				
Colletes		+		+
Hylaeus	+–	+–		+
Andrenidae				
Calliopsis	+–	+–		+
others	+			+
Halictidae	+			+
Melittidae				
Macropis	+–	+–	+	
Hesperapis		+	+	
Megachilidae				
Lithurgus		+		+
others		+	+	
Anthophoridae				
Exomalopsis	+		+	
Ancyloscelis	+		+	
other anthophorines		+	+	
Ceratina	+		+	
Xylocopa		+	+	
Apidae		+		

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MELANISM IN *PANTHEA FURCILLA* (PACKARD) (LEPIDOPTERA, NOCTUIDAE): FIELD STUDIES IN CENTRAL MASSACHUSETTS

Tobin K. Jones

Abstract.—Jones, Tobin K., Department of Zoology, University of Massachusetts, Amherst, Massachusetts 01003.—Field studies were undertaken to determine the nature and extent of melanism in two populations of the cryptic moth, *Panthea furcilla.* Melanic frequencies significantly increased over a three year period in both populations of *P. furcilla* sampled. Predation experiments showed that melanics suffer less predation than typicals. However, life expectancies for typical and melanic morphs were nearly equal as computed from mark-release-recapture data. Accordingly it is suggested that one advantage melanics enjoy is their greater vigor prior to the imaginal stage. Acid-rainfall, as a Northeast regional problem, is advanced as a possible cause for the increase in melanic frequencies.

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Valuable opportunities to view evolution at work exist in the study of melanism in moths. Although extensive work by Kettlewell and his associates with melanism in British moths has provided us with the "most striking evolutionary change in nature ever to be witnessed by man" (Kettlewell, 1973), the occurrence of melanism in North American moths has attracted relatively little attention. Owen (1961, 1962) described the occurrence of melanism in six North American geometrid species. Klots (1964, 1966, 1968a, b) provided data on wild-caught samples of two noctuid species in Putnam, Conn. and recorded results of breeding experiments with one of these, *Panthea furcilla* (Packard). Sargent (1969) investigated background selections in *Phigalia titea* (Cramer) (Geometridae) and analyzed melanic frequencies in wild-caught samples of *P. titea* (1971) and five other noctuid and geometrid species, including *P. furcilla* (1974).

The present study deals with melanism in *P. furcilla* and was stimulated, in part, by pleas for carefully acquired data on melanism in North America (Owen 1962, Klots 1966, Sargent 1971, 1974). Data based on accumulated records of wild-caught individuals from two populations of *P. furcilla* in central Massachusetts from 1974–76 are presented. Mark/recapture studies were carried out in both populations to determine population size and individual morph longevity. Possible differential predation pressures affecting the two morphs in both populations were investigated in a predation experiment. In addition, possible selective agents affecting the evolution of melanism in *P. furcilla* are discussed.

Panthea furcilla is bivoltine in New England with adults emerging in early June and late July. The two generations overlap to some extent as adults are available over most of the summer. The adults are attracted to fluorescent lights and easily captured by hand due to their relatively calm behavior near such lights. Males are more commonly taken than females.

Details of mating and rearing *P. furcilla* in captivity are outlined by Ginevan (1971). The small (0.75 mm), spherical eggs are laid on the needles of the larval foodplant, white pine (*Pinus strobus*). The larvae hatch in about seven days and feed for two to three weeks before pupating. Larval coloration is dimorphic, dark and light, but the genetic control of melanism in the larvae is unrelated to that determining melanism in the imagoes (Klots, 1966). The pupae may be naked, or wrapped in a cocoon which may also be dark or light colored, but again this dimorphism appears unrelated to adult coloration.

The melanic adult form, *atrescens* (McDunnough), is variable but usually distinct from the paler typical form. Photographs of both forms are available in Ginevan (1971). Ginevan (1971), working with moths from the Amherst, Mass. area, concluded that melanism in the *P. furcilla* imago is determined by a single, dominant, sex-linked gene. However, Klots (1966, 1968) suggested that inheritance of melanic forms is multifactorial in *P. furcilla.* He described melanic forms as wholly melanic, strongly melanistic, and slightly melanistic, in contrast to Ginevan, who recognized only one melanic form. Having had the opportunity to view specimens from both collections, I believe that Klots' wholly melanic phenotype is not present in the Amherst area. Thus, there may be genetic factors promoting melanism in the Putnam, Conn. area that are absent in Amherst. Certainly the great variation in the melanic phenotypes warrants further investigation, particularly with regard to the degree of dominance the melanic alleles possess.

Methods

Two areas were sampled in Franklin Co. of north central Massachusetts. One area, located in Shutesbury, is characterized by a mixed deciduous and coniferous forest. The most common deciduous trees are hickories (*Carya glabra* and *C. ovata*), birches (*Betula papyrifera* and *B. lento*), and oaks (*Quercus velutina* and *Q. alba*). Numerous saplings of all three deciduous species are present. A forty year old stand of white pine (*Pinus strobus*), however, predominates the forest. The second area is located ten miles north in Sunderland. There, large white pines, dating back one hundred years or more, dominate a mainly coniferous forest. This second area lacks the dense forest canopy seen in Shutesbury, and the upper trunks

of the old pines receive full light the entire day. Although both areas are ostensibly free from pollution, the pine trunks are bare of lichens.

The moths were collected at two 40-watt black light fluorescent tubes and two 40-watt cool, white fluorescent tubes. The use of black lights with white lights was most effective. The black lights were presumably more attractive to the moths, while the white lights seemed to exert a calming effect on them. The moths were captured by hand and placed individually in small glass bottles in ice brought to the site. The majority of the moths were subsequently used in predation experiments or marked and released as part of a mark/recapture study.

In the predation experiments, the moths were frozen and then affixed to tree trunks with the glue-like substance, tanglefoot. Several moths were placed onto trees the same day, each tree receiving one moth. Groups of six to eight trees were selected in different parts of the woods, and the moths were placed at eye level with the body vertical and the head up. Each moth's crypticity was scored by determining the distance from the tree at which that moth's form became recognizable. An observer, located 35 feet from the moth, moved toward the moth until its form was distinguished. The cryptic rating then was determined by the distance of the observer from the tree. On a scale of +3 to –3, each number represented an interval of five feet (in which the moth was discerned). Thus, a +3 rating was given for moths perceived only within five feet of the tree, a +2 rating for moths sighted 5–10 feet from the tree, and so on until a –3 rating was given for moths whose form was recognizable 30 feet or more from the tree. The trees with moths were visited each day and absentees noted.

In the mark/recapture study, moths were marked with a small dot of enamel paint on various upperside parts of the left and right forewings. The color of the paint and the position of the dot coded for the day of the capture. The moths were released the morning following their capture at various points throughout the collection area. Subsequent recaptures were noted and the data treated as described by Fisher and Ford (1947).

Data presented in this paper were analyzed by either the 2×2 Independence test (using G-statistic) or the $R \times C$ Association test (using G-statistic) (Sokal and Rohlf, 1969). The two tests are similar, the 2×2 test being used when $df = 1$ and the $R \times C$ test when the $df > 1$.

Analysis of Captures

The numbers of typical and melanic individuals of *P. furcilla* collected over three years in Shutesbury and Sunderland are presented in Table 1. There was an apparent increase in frequency of melanic forms in both populations over the three years. The increase in the percentage of melanics in Shutesbury from 1974–76 ($G = 8.08$, $P < .005$) may be somewhat mis-

Table 1. Total numbers of typical and melanic *P. furcilla* taken over three years in Shutesbury, Mass. and Sunderland, Mass.

	1974			1975			1976			
	Jun	Aug	Total	Jun	Aug	Total	Jun	Aug	Total	Totals
					Shutesbury					
Typical	107	36	143	—	—	—	—	95	95	238
Melanic	178	90	268	—	—	—	—	278	278	546
% Melanic	62.4	71.4	65.2	—	—	—	—	74.5	74.5	69.6
					Sunderland					
Typical	51	46	97	33	100	133	124	—	124	354
Melanic	180	133	313	107	361	468	565	—	565	1346
% Melanic	77.9	74.3	76.3	76.5	78.3	77.9	82.0	—	82.0	79.2

leading in that the 1974 totals include both June and August collections while the 1976 totals are from August only. The melanic frequency for June 1974 is almost significantly less than August 1974 ($G = 3.16$, $P < .08$), and the August 1974 and August 1976 percentages are not significantly different ($G = .48$, $P < .5$). Thus, there may be an increase in the percentage of melanism over the summer in Shutesbury, rather than an increase in melanic frequencies in the three years of collecting.

In Sunderland, the 5.7% difference between the 1974 and 1976 samples is significant ($G = 6.0$, $P < .05$), and melanic frequencies there showed no significant fluctuations between generations in a single summer. Differences between melanic frequencies from Sunderland and Shutesbury proved highly significant when 1974 totals ($G = 5.6$, $P < .02$) or three year totals ($G = 26.14$, $P < .0001$) were compared.

Table 2. Numbers of typical and melanic *P. furcilla* taken by half-hours in Sunderland and Shutesbury, including the percentage of the season's total number captured in each half hour.

	Sunderland 1976			Shutesbury 1976		
Hours (ESDT)	Typ/Mel	% total typical	% total melanic	Typ/Mel	% total typical	% total melanic
2150–2199 h	0/3	0.0	0.7	10/39	10.5	14.0
2200–2249 h	2/10	1.8	2.2	31/94	32.6	33.8
2250–2299 h	4/72	3.6	16.0	30/81	31.6	29.1
2300–2349 h	29/133	26.1	29.6	18/52	18.9	18.7
2350–2399 h	54/153	48.6	34.1	5/8	5.3	2.9
2400–2449 h	22/78	19.9	17.4	1/4	1.1	1.5
Total	111/449	100.0	100.0	95/278	100.0	100.0

Table 3. Mark/recapture data of typical and melanic morphs in Sunderland in 1975.

	July		August															
	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Typicals																		
1	–	–	0	3	0	0	0	–	–	–	–	0	2	–	0	0	2	0
2			2	0	0	0	2	–	–	–	–	0	0	–	0	0	0	0
3				1	0	0	1	–	–	–	–	0	0	–	0	0	0	0
4					0	0	0	–	–	–	–	0	0	–	0	1	0	0
Captures	11	–	10	13	3	2	7	–	–	–	–	9	6	–	7	9	2	1
Releases	10	–	9	13	3	2	7	–	–	–	–	9	6	–	7	9	2	1
Melanics																		
1	–	–	0	19	2	2	–	–	–	–	–	0	3	–	0	3	0	0
2			14	0	1	3	–	–	–	–	–	0	0	–	1	0	0	0
3				10	0	1	–	–	–	–	–	0	0	–	0	0	0	0
4					0	1	–	–	–	–	–	0	0	–	0	0	0	0
5						0	–	–	–	–	–	1	0	–	0	0	0	0
6							–	–	–	–	–	1	0	–	0	0	0	0
Captures	36	–	29	44	13	21	–	–	–	–	–	55	15	–	47	29	2	0
Releases	36	–	25	44	13	20	–	–	–	–	–	55	15	–	45	29	2	0

The numbers of typicals and melanics captured at half-hour intervals at Sunderland and Shutesbury during 1976 are presented in Table 2. In Sunderland, melanics were taken relatively earlier in the evening than typicals ($G = 20.3$, $P < .002$). There the mean time of capture for melanics and typicals was approximately 2345 h and 2379 h, respectively. In Shutesbury, there was no difference with respect to times of capture of the two morphs.

Table 2 also shows an earlier flying time for the Shutesbury population compared to the Sunderland population ($G = 475.6$, $P < .0001$). In Shutesbury, the moths began flying at 2150 h, with a mean time of capture at 2279 h. On Sunderland, most moths had not begun flying until nearly 2300 h, with a mean time of capture at 2359 h.

Mark/Recapture Experiment

Tables 3–5 present the mark/recapture data necessary for the calculation of survival rates, as outlined by Fisher and Ford (1947), and these tables follow the format of Sheppard (1951). Each table is made up of vertical columns, headed by the appropriate date. The numbers captured and released each day are found at the foot of the column. The numbers in the

Table 4. Mark/recapture data of typical and melanic morphs in Sunderland in 1976.

		June 1976																													July 1976				
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5
Typicals																																			
	1	–	0	–	0	–	0	1	–	0	–	0	0	–	0	1	5	–	0	–	–	0	–	–	0	0	–	0	0	–	0	–	0	–	0
Days	2			–	0	–	0	0	–	0	–	0	0	–	0	0	1	–	0	–	–	0	–	–	0	0	–	0	0	–	0	–	0	–	1
from	3				2	–	0	0	–	0	–	0	0	–	0	0	0	–	0	–	–	0	–	–	0	0	–	0	1	–	0	–	0	–	0
first	4					–	0	0	–	0	–	0	0	–	0	0	0	–	0	–	–	0	–	–	0	0	–	0	1	–	0	–	0	–	1
release	5						0	0	–	0	–	0	0	–	0	0	0	–	0	–	–	0	–	–	0	0	–	0	0	–	0	–	0	–	0
	6							0	–	0	–	0	0	–	0	0	0	–	1	–	–	0	–	–	0	0	–	0	0	–	0	–	0	–	0
Captures		5	3	–	4	–	2	2	–	1	–	2	9	–	7	8	18	–	2	–	–	3	–	–	13	8	–	1	4	–	1	–	3	–	7
Releases		5	3	–	4	–	2	2	–	1	–	0	8	–	6	7	12	–	1	–	–	0	–	–	9	3	–	1	3	–	1	–	3	–	0
Melanics																																			
	1	–	4	–	0	–	0	3	–	0	–	0	0	–	0	3	12	–	0	–	–	0	–	–	0	2	–	0	7	–	0	–	0	–	0
	2			–	6	–	6	0	–	2	–	0	0	–	3	0	3	–	0	–	–	0	–	–	0	0	–	6	0	–	11	–	6	–	2
Days	3				2	–	0	3	–	2	–	0	0	–	0	1	0	–	1	–	–	0	–	–	2	0	–	2	5	–	5	–	0	–	0
from	4					–	2	0	–	0	–	0	0	–	0	0	4	–	0	–	–	0	–	–	0	3	–	0	4	–	3	–	1	–	0
first	5						2	0	–	1	–	0	0	–	1	0	0	–	0	–	–	0	–	–	0	0	–	0	0	–	2	–	1	–	0
release	6							1	–	0	–	0	0	–	0	0	0	–	5	–	–	0	–	–	0	0	–	1	0	–	0	–	0	–	0
	7								–	0	–	0	0	–	0	0	0	–	0	–	–	0	–	–	0	0	–	0	1	–	0	–	0	–	0
	8									1	–	0	0	–	0	0	0	–	0	–	–	0	–	–	0	0	–	0	0	–	0	–	0	–	0
Captures		8	17	–	22	–	19	18	–	14	–	2	42	–	15	25	62	–	11	–	–	41	–	–	36	32	–	26	36	–	39	–	22	–	19
Releases		8	17	–	22	–	19	17	–	14	–	0	40	–	15	22	46	–	5	–	–	24	–	–	27	27	–	19	31	–	32	–	10	–	0

Table 5. Mark/recapture data of typical and melanic morphs in Shutesbury in August 1976.

	11	12	13	14	15	16	17	18	19	20
				Typicals						
1	–	4	2	0	–	0	1	2	–	0
2			1	0	–	1	0	2	–	1
3				0	–	0	1	0	–	0
4					–	0	0	1	–	0
Captures	7	11	23	13	–	4	14	15	–	8
Releases	7	11	20	12	–	4	13	9	–	0
				Melanics						
1	–	6	6	4	–	0	5	8	–	0
2			2	0	–	1	0	2	–	10
3				1	–	0	1	0	–	3
Captures	21	27	51	34	–	15	39	49	–	42
Releases	21	27	48	34	–	15	30	44	–	0

body of the table refer to the number of marks on recaptured moths and the intervals of time from their capture and the day coded for by the mark, i.e., a single moth with two marks is counted as two recaptures. The date of each recapture is located at the top of each column and the time, in days, from its first release is at the left-hand side of the table. Only males were used in these mark/recapture experiments.

There was no appreciable difference between melanic and typical survival rates except in Sunderland during the early summer (see Table 6).

Predation Experiments

Tables 7 and 8 present the data from the predation experiments performed in Shutesbury and Sunderland. The results of these experiments are sum-

Table 6. Estimated daily survival rates and population sizes for melanic and typical males in Shutesbury and Sunderland.

Date	Locality	Melanic daily survival rate	Typical daily survival rate	Estimated daily population size
7/30–8/16/75	Sunderland	0.48	0.52	50–200
6/2–7/5/76	Sunderland	0.65	0.52	60–260
8/1–8/20/76	Shutesbury	0.37	0.37	50–300

Table 7. Initial numbers of cryptically rated moths placed on tree and subsequent numbers present after daily inspection in Sunderland.

Cryptic rating:		−3	−2	−1	0	+1	+2	+3	Totals
					Typicals				
Initial number:		3	0	0	5	5	2	0	15
	1	2			3	4	2		11
Days after	2	1			2	4	1		8
placement:	3	1			1	2	1		5
	4	1			1	2	1		5
Totals		5			7	12	5		29
					Melanics				
Initial number:		1	0	1	0	2	8	16	28
	1	1		0		0	8	15	24
Days after	2	1		0		0	6	14	21
placement:	3	0		0		0	3	12	15
	4	0		0		0	3	12	15
Totals		2		0		0	20	53	75

marized in Table 9. Melanic individuals apparently enjoyed a cryptic advantage in both areas, as indicated by the average cryptic ratings and the relative survival rates. The average cryptic rating for each group was computed by summing the moths' cryptic ratings and dividing by the total

Table 8. Initial numbers of cryptically rated moths placed on trees and subsequent numbers present after daily inspection in Shutesbury.

Cryptic rating:		−3	−2	−1	0	+1	+2	+3	Totals
					Typicals				
Initial number:		2	3	5	3	3	2	0	18
	1	1	2	4	3	3	2		15
Days after	2	1	1	3	2	3	1		11
placement:	3	0	1	1	2	2	1		7
	4	0	1	0	0	2	1		4
Totals		2	5	8	7	10	5		37
					Melanics				
Initial number		0	0	0	3	7	10	10	30
	1				3	4	8	10	25
Days after	2				2	3	7	8	20
placement:	3				2	2	7	8	19
	4				2	2	4	7	15
Totals					9	11	26	33	79

Table 9. Data from predation experiments, cryptic ratings and relative survival of typical and melanic moths.

	Shutesbury		Sunderland	
	Melanics	Typicals	Melanics	Typicals
Numbers exposed	30	18	28	15
Survival in days	79	37	75	29
Average survival	2.63	2.05	2.68	1.93
Relative survival	0.98	0.76	1.00	0.72
Average cryptic rating	+1.90	−0.56	+2.21	0.00

number of individuals, e.g., 66/28 = 2.21 for melanics in Sunderland. The relative survival figures were determined by dividing the average survival (days/individual) value for each group by the greatest longevity (2.68 days for melanics in Sunderland). Average survival values for each group were computed by dividing the days of survival by the numbers of moths exposed, e.g., 75/28 = 2.68 days/individual for melanics in Sunderland. Relative survival figures were almost identical for the two areas despite the greater cryptic ratings in Sunderland.

Discussion

Melanism in *P. furcilla* may be in a transient state. The high and apparently increasing frequencies of melanism in two populations of *P. furcilla* indicates a current selective advantage for melanic individuals over their typical counterparts. Similar melanic frequencies in at least two populations other than those reported here (Klots, 1963; Sargent, 1974) demonstrate that the advantage of melanism is widespread. The diversity of the forests inhabited by these four populations, in terms of tree species and age structure of the pines, suggests that the melanics' superiority is not dependent upon any particular type of forest. This is not to say that forest characteristics have no variable effects upon the *P. furcilla* morphs.

The significantly different frequencies in Sunderland and Shutesbury invite comparisons between the areas for factors that may be favoring melanism. Several differences in data collected at Shutesbury and Sunderland are notable. In Shutesbury, *P. furcilla* began flying earlier than in Sunderland. There was no difference in flying times of melanic and typical morphs in Shutesbury, but melanics were caught earlier than typicals in Sunderland. The earlier flying times for both typicals and melanics in Shutesbury may be due to the denser forest canopy causing the ambient light levels to drop more rapidly at dusk. The accelerated nightfall might then prompt both morphs to leave their cryptic hiding places earlier.

The mark/recapture studies showed a shorter survival rate for melanic

and typical imagines in Shutesbury as compared to Sunderland. Whatever reduced adult longevity in Shutesbury affected both typicals and melanics equally. It was observed that the number of birds and diversity of species was much greater there than in Sunderland. In particular, the Black-and-White Warbler (*Mniotilta varia*), absent in Sunderland, was observed in great numbers in Shutesbury. Its systematic search of the trunks and limbs of trees would presumably make it a formidable predator of cryptic moths. The predation experiment showed that melanics were more cryptic than typicals and suffered less predation in both Sunderland and Shutesbury.

The observations and experiments reported here suggest that melanic adults may have a slight advantage over typicals due to a cryptic superiority. Survival rates, however, were similar for the two morphs, except for a June population in Sunderland. Perhaps then, other factors are selecting for melanism in *P. furcilla*. Sargent (1971) has suggested this possibility with regard to melanism in *P. titea*, and indeed, genes for melanism have been associated with greater viability in several species. Ford (1940) showed that heterozygous melanic individuals of *Cleora repandata* are more resistant to starvation than their typical sibs, and Kettlewell (1958), working with *Biston betularia*, demonstrated that the melanic form, *carbonaria*, is more resistant to the effects of eating soot-covered foliage.

It is interesting to note that pantheines characteristically exhibit melanism, suggesting that melanism probably arose in some ancestral stock. Several close relatives of *P. furcilla* show melanic forms. In the Pacific Northwest, for example, *P. portlandia* is dimorphic having a light brown melanic form. Other pantheines in the Northeast that have melanism similar to *P. furcilla* are *Demas propinquilinea* and *Charadra deridens* (Klots, 1964).

Kettlewell (1973) states that melanism is frequently found in regions having indigenous coniferous forests, and was probably common in North America before the succession of conifers by deciduous trees 10,000 years ago. Klots (1966) has hypothesized that *P. furcilla* had evolved a stable, balanced polymorphism in the pre-Columbian forest. Its population was presumably very dark and today's typical was undoubtedly rare. Klots suggests that *P. furcilla* changed from a predominantly dark population to a much lighter one in response to the removal of the indigenous forests for agriculture. Then, with the decline of agriculture in the 20th century, the New England countryside became reforested, and the melanic form was selected for again. Thus, Klots views the present melanism in *P. furcilla* as non-industrial in nature.

This hypothesis seems plausible except that one might imagine that somewhere in those forests untouched by agriculture, melanics would have continued to exist in appreciable numbers. The fact that the first melanic of *P. furcilla* was not collected until 1938 (McDunnough, 1942)

and that these melanics now make up considerable portions of populations throughout New England, suggest that the factors currently selecting for melanism are more recent in origin.

Kettlewell (1973) defines industrial melanics as dark individuals selected for by the effects of industrialization. These effects include the deposition of soot and removal of epiphytic lichens, both acting to darken the tree trunks upon which bark-like moths rest. Therefore, increasing melanism in industrial areas is usually attributed to a cryptic advantage of melanics over typicals, which accordingly leads to lowered predation on melanic forms. The substantial evidence for this position is summarized in Kettlewell (1973).

There are studies, however, which suggest that a cryptic advantage may not account for all recent cases of increasing melanism. Increased melanic frequencies of the warningly-colored beetle, *Adalia bipunctata* L., in industrial areas (Creed, 1966) and inappropriate background selections by *P. titea* melanics (Sargent, 1969) are examples. Thus, atmospheric factors of industrial origin may exist that are associated with melanism in ways other than the darkening of the environment.

Lees, Creed, and Duckett (1973) found that the levels of sulfur dioxide (SO_2) were correlated with high melanic frequencies in *B. betularia.* This finding leads me to suggest that SO_2 may be a regional factor selecting particularly for melanism in *P. furcilla* and other species in New England. The Northeast, due to its geographical location and the prevailing weather patterns, is directly downwind from major industrial centers in the Midwest. SO_2 is produced from the combustion of fossil fuels (coal, oil, etc.) and is capable of traveling hundreds of miles before settling down or washing out of the atmosphere by rain (Cogbill, 1974). In the upper atmosphere, SO_2 reacts with water to form sulfuric acid (H_2SO_4), and the result is extremely acidic rainfall, particularly during the summer months when the weather patterns travel predominantly from the southeast. At that time rain samples with a pH lower than 3.00 have been found, and samples with pH values of less than 4.00 are commonly taken throughout New England (Likens, 1974). In the Amherst area, I have measured the acid content of rainwater and have found samples with pH values as low as 3.85. Since SO_2 particles are deposited on pine needles, there were occasions during the summer (after a long dry spell had been broken by a thunderstorm) when water collected beneath white pine trees was ten times as acidic as the rain itself.

The hypothesis that increasing acidity of rain might be causing increasing melanism in *P. furcilla* is particularly attractive because the two phenomena are coincidental in time. The rapid increase in melanism of *P. furcilla* probably took place in the mid-1950's, and while there are no reports of rain pH values before 1962 for the New England area, a recon-

struction prediction can be made from earlier studies of precipitation chemistry (Cogbill, 1974). Such data suggest that the acidification process began in the early 1950's. Of course, SO_2 had been produced in great quantities before this time, but the pH of the rain had not altered because of the buffering ability of the atmosphere (Likens, 1974). The alkaline ash particles released from the combustion of coal and wood had served to neutralize the acid produced. However, with the advent of oil, electric, and natural gas heating for homes, this neutralizing factor was lost. The pH started to decrease, slowly at first due to residual buffering capacities of the atmosphere, but accelerating in the last fifteen years and likely to continue accelerating (Likens, 1974). Therefore, if melanics are more resistant to acid rain or its effects, then their numbers in populations all over New England should continue to rise.

The larval life stage would likely receive the brunt of this type of pollution. Not only would the larvae be exposed to acidic conditions, they would have to ingest the possibly toxic SO_2 particles that had settled on their food. The nutrition of the needles is also diminished by acidic rain, as valuable minerals in the form of cations are leached out of the plant tissue and replaced by H^+ ions (Eaton et al., 1973).

Experiments have been initiated to test for differential viability among the larval forms of melanics and typicals on vegetation treated with "acid rain." Although the experiments are not completed, initial results suggest that the acid content does have some effect. Fewer larvae feeding on pine needles sprayed with rainwater adjusted to low pH values have pupated, and those that have done so are considerably smaller than pupae from control groups.

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A DESCRIPTION OF A NEW NEARCTIC SPECIES OF *XYLOMYA* (DIPTERA: XYLOMYIDAE)

Carey E. Vasey

Abstract.—Vasey, Carey E., Biology Department, State University College of Arts and Science, Geneseo, N.Y. 14454.—*Xylomya terminalis*, n. sp. collected from Allegany County, New York is described. Three specimens, two from New York State and one from Kalamazoo County, Michigan are included in the type series.

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Introduction

A single female specimen of *Xylomya* was collected from a wooded area near the town of Fillmore, Allegany County, New York on July 11, 1976 by W. B. Sinnamon. This genus is poorly known and has received little attention except for its inclusion in the studies of Leonard (1930) and Steyskal (1947). The latter revised the genus (as *Xylomyia*) and recognized six Nearctic species previously named and described one additional species as new.

An attempt to identify the specimen at hand using Steyskal's key runs smoothly until couplet five is reached. *Xylomya terminalis*, n. sp. is distinguished from *X. aterrima* Johnson by the yellow palpi which are black in the latter species and from *X. tenthredinoides* (van der Wulp) which has reddish terminalia rather than blackish as in *X. terminalis*. While the palpi of *X. tenthredinoides* are also yellow, and the terminalia of *X. aterrima* are black like that of *X. terminalis*, the overall nature of the thorax and abdomen of the latter is unlike that of either species.

The holotype will be deposited in the collections of Cornell University. (C.U. Type No. 5119).

Xylomya terminalis, n. sp.

Holotype.—Length, 13.5 mm. Wing, 11 mm.

Head.—First antennal segment dark-brown, one and one-half times longer than wide. Second antennal segment, dorsal aspect dark-brown, ventral and lateral areas light-brown, nearly as long as wide. First 2 segments with numerous black hairs. Flagellum with 8 visible joints, all of which are bare except terminal one which bears many coarse black hairs. Frons, a thin, black shiny callus nearly twice as long as wide. Ocelli 3, on slightly elevated tubercle on vertex. Face with silvery pubescence above,

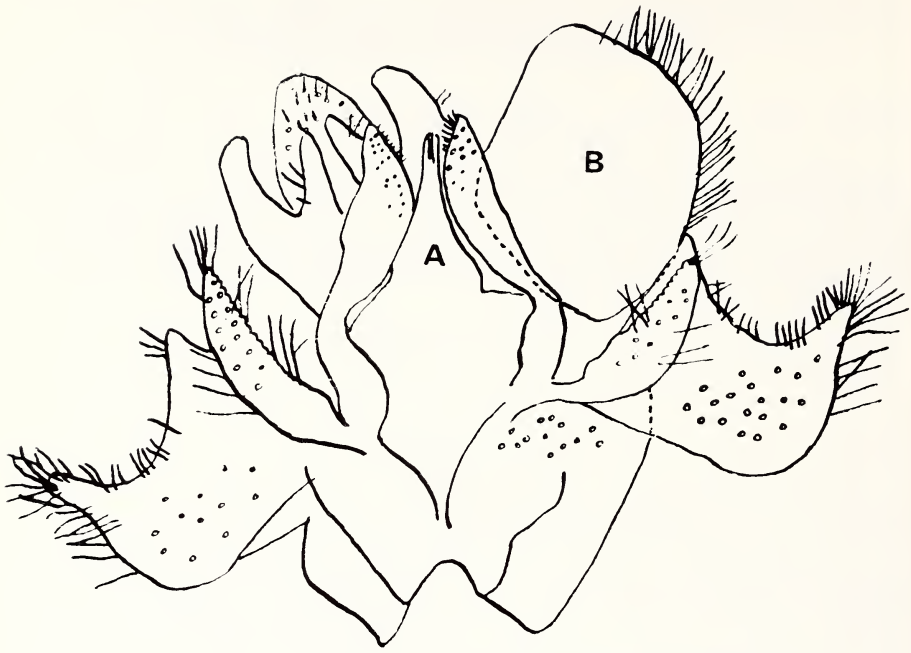

Fig. 1. Ventral view of male genitalia of *Xylomya terminalis*. Lobe designated B has been removed from the right side in order to see parts clearly. Because homologies of male genitalia of *Xylomya* sp. have not been established, except for the aedeagus (designated A) the other components have not been labeled.

on either side of and below antennal bases. Palpi (Fig. 2) yellow, obtuse at tip bearing numerous yellow hairs. Head separated from thorax by distinct collar-like, yellow cervix. Outer border of occipital and post-occipital area fringed with long yellow hairs, area in back of eyes with silver pubescence.

Thorax.—Mesonotum subshining, dark-brown and yellow so as to form a pattern as follows: Broad, brown, median stripe extending from anterior edge to area just caudad to transverse suture. Latero-dorsal areas anterior to transverse suture with large, oval, dark-brown spots. Areas between brown markings yellow. Humeral and postalar calli yellow. Mesoscutellum yellow, bordered laterally and anteriorly by dark-brown. Lateral areas posterior to transverse suture and anterior to postalar calli dark-brown fusing with median brown stripe from anterior end. Entire dorsum with numerous golden hairs, arranged in patches, curving in different directions. Propleuron yellow, infuscated with brown. Mesopleuron dark-brown anteriorly, separated from posterior yellow portion by irregular, somewhat anteriorly curved line extending from the spiracle just below

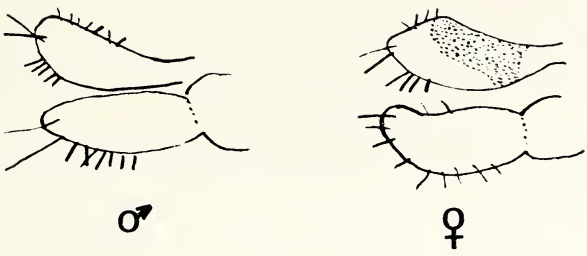

Fig. 2. Profiles of the left palpi of *Xylomya terminalis.*

humeral callus to about base of the middle coxae. Wings clear, anterior half brownish tint, venation brown. Halteres pale yellow. Legs: Prothoracic and mesothoracic legs yellow, terminal tarsal segments infuscate. Metathoracic legs, yellow, inner surfaces of trochanters dark-brown, distal thirds of femurs and tibiae dark-brown; terminal segments of tarsi, infuscate.

Abdomen.—Anterior border of first segment with a continuous black band, remainder of segment one and segments 2–4 yellow with brownish infuscations. Terminal 4 segments and terminalia black.

Paratypes.—1♂ Gull Lake Biological Station, Kalamazoo Co., Michigan: 22 July 1966 (R. L. Fischer); 1♂ Rochester, New York: July 1968 (R. Duffield); 1♀ Ithaca, New York: 26 June 1965 (D. L. Stephan).

Paratypes will be deposited in the collections of Cornell University and United States National Museum, Smithsonian Institution.

Variations.—The male paratypes are slightly smaller than the female holotype, ranging between 12.5 mm and 13.0 mm in length. The paratype measures 14.0 mm in length. The type series of specimens is uniform in appearance. The important difference is in the degree of infuscation on the abdominal segments. In all cases the degree of dark-brown bands on first abdominal segment is greater than that described for the holotype. The paratype has much greater degree of fusion of brown and yellow in segments 2–4 than holotype. In all specimens, the posterior 4 segments and terminalia are dark-brown to black. The male genitalia are illustrated in Fig. 1.

Acknowledgments

The loan of the paratypes used in this study by Dr. L. L. Pechuman of Cornell University and by Mr. G. C. Steyskal of the Systematic Entomology Laboratory, U.S.D.A. is greatly appreciated. I also want to thank both for their advice and consultation and a special note of gratitude to Dr. Pechuman for reading the manuscript.

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DROSOPHILA COURTSHIP: DECAPITATED QUINARIA GROUP FEMALES

Joseph Grossfield

Abstract.—Grossfield, Joseph, Department of Biology, City College, N.Y., N.Y., 10031.—The behavior of three quinaria group species of *Drosophila*, *D. falleni*, *D. occidentalis* and *D. guttifera* was observed. Males of each species were given a choice of normal and decapitated conspecific females. Males of *D. occidentalis* and *D. guttifera* fail to inseminate any decapitated females while *D. falleni* inseminates significantly fewer decapitated females. Normal females are courted preferentially as evidenced by either the number or the sequence of courtships. Of the three species, *D. guttifera* is the most effective in converting courtship to inseminations with an effective courtship ratio (C/I) of 1.2. Decapitated females do not give acceptance signals. This excludes the possibility that this motor pattern is part of a reflex arc analagous with vertebrates. For some species visual stimuli are involved within the courtship sequence as well as in the initiation of courtship. The recognition by males of these visual signals serves as a gating point for the next step in his courtship sequence. The acceptance response can serve as trigger mechanism for the male motor response. The behavioral architecture of these species differs from the *D. melanogaster* pattern. The discriminatory mechanisms responsible for specific stimulus recognition represent the intrinsic component of behavior least sensitive to environmental modification.

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Introduction

Spieth (1966) used decapitated females to study factors responsible for the initiation of courtship in *Drosphila* and indicated the importance of the female's CNS in interpreting stimuli of male origin. Subsequent studies (Grossfield, 1970a, 1972) reported that males of species which require light in order to mate do not court decapitated females unless the approach is such that the effect of the operation is not evident. This work also suggested that such species use visual cues even after the initiation of courtship. The potential utility of light dependent species for dissection of specific sign stimuli involving a single sensory modality prompts a more detailed look at the behavioral organization of such species compared with more well-known species. Most studies of courtship behavior have used species in the melanogaster, obscura, and willistoni species groups in the subgenus Sophophora (Spieth, 1968).

Table 1. Number of females dissected (n) and percent inseminated (%) upon presentation of males of each species with a choice between normal and decapitated females. Flies of each species are 11, 7, or 10 days of age, respectively.

	Insemination				Number of courtships				
	Normal		Decapitated			(a) Normal	(b) Decapit		Courtship ratio
	n	%	n	%	χ^{2c}	♀♀	♀♀	χ^{2d}	a/b
D. falleni	50	74.0	50	12.0	24.7	13	5	n.s.	2.6
D. occidentalis	30	80.0	30	0.0	36.7	17	5	n.s.	3.4
D. guttifera	75	92.0	75	0.0	124.1	62	18	11.6	3.4

[c] All chi-square values calculated with the Yates correction (Croxton, 1953) and all are significant at the .001 level.

[d] Calculated on the basis of a = b.

Thus, several species from the quinaria group of the other major subgenus were chosen. The quinaria species represent a clearly definable group which is quite divergent in many aspects of its biology (Patterson & Stone, 1952; Throckmorton, 1962; Spieth, 1952). Spieth (1966) also reported that females of all species he used failed to give acceptance responses. The species he observed included a large sample but did not include certain types of acceptance response. These particular quinaria group species were chosen to see whether their females performed similarly. *D. falleni* is a species whose mating is strongly inhibited by darkness (Class II or facultative dark maters, Grossfield, 1971), while *D. guttifera* shows complete inhibition of mating by darkness (Class III or obligatory illumination). The strain of *D. occidentalis* used shows a small degree of mating in darkness (Grossfield, 1966). Since the acceptance response appears to serve as a gating point, or switch in some of these species, it may provide information concerning the neural organization of behavior. The advantage of using such species lies in their possession of distinct recognition signals which allow a discrete qualitative evaluation of unique components, contrasted with quantitative measures which might be expected to show a greater degree of inter-strain variation.

Procedures

Mature virgin females were beheaded two to four hours preceding their introduction, together with normal males, into observation vials. Decapitation was performed under brief, humidified CO_2 anaesthetization. Normal females for each vial were treated identically but not beheaded. The University of Texas collection number is listed for each species pre-

ceding the behavioral description. Each vial had five normal males and an equal number of both normal and decapitated females. Vials were observed under a stereozoom microscope for 1 h following the introduction of both sexes and behavioral details as well as the number of courtships were noted. At the end of 24 h the females were dissected, and the number inseminated determined by microscopic examination of both the ventral receptacle and spermathecae for presence of sperm. All observations and fly stocks were in a 21 ± 1°C room illuminated for 12 h per day. The observation period was from 1700–1800 h since, under these conditions, these species are more sexually active at this time.

Behavior of Species
(See Table 1)

All basic courtship patterns are taken from Spieth (1952). *D. falleni* is there listed as *D. transversa* (see Wheeler, 1960) for a discussion of this change.

Decapitated females, if they do not decamp at first contact with a courting male, use their legs, midlegs especially, to fend off males. In many cases this fending activity breaks contact of the male's foretarsi with the female's abdomen. As Spieth (1966) reported for the species he used, the behavioral repertoire of decapitated females seems limited to decamping from bothersome stimuli, such as courting males, certain cleaning activities, and general repelling actions with their legs and abdomen.

D. falleni—1062.6

The male, after tapping, positions himself behind the female and vibrates one wing in bursts. He then lunges onto the female and attempts intromission. A receptive female spreads her vaginal plates while an unreceptive one repels by fluttering, kicking, depressing or decamping. Males may circle a nonreceptive female while scissoring one wing.

These males inseminate significantly more normal females. In general, males treat decapitated females in a cursory fashion. A male approaching a decapitated female from the front or side generally ignores the female. Males may position at the rear and vibrate one wing in a few desultory bursts before departing. Only if the approach is made directly behind a decapitated female does a male continue courting and attempt mounting. With such rear approaches, males begin to circle the female, reach the front and walk off. Decapitated females generally remain stationary but for attempted mounting, which constitutes first contact, in which case they decamp.

The proportion of decapitated females inseminated is the same as the

proportion of normal females inseminated in darkness (Grossfield, 1966). This may indicate that a certain minority of the population is less dependent on certain, presumably visual, cues than the rest.

D. occidentalis—2175.3

The male taps, goes to the rear and strokes the dorsal portion of the female's abdomen, simultaneously flicking one wing and licking the ovipositor. A receptive female spreads her wings 90° and spreads her vaginal plates. The male then mounts and inserts. Non-receptive females repel by kicking, fluttering their wings, or elevating their abdomens; occasionally males may attempt mounting non-receptive females.

Initial courtship of females shifts rapidly to courtship of normal females. Males court decapitated females briefly and walk off. Thus, although there is no significant difference in the total number of courtships directed towards the two types of females, the temporal distribution of courtships is significant. Males which court for long periods of time do so at the rear. Even with those males that court for extended periods (over 5 min) no female gives an acceptance response, nor do any males attempt to mount. Few females decamp and most merely engage in fending with the metathoracic legs for intermittent brief periods during the courtships.

D. guttifera—2086.3

The male taps, goes to the rear of the female, approaches with outstretched proboscis and licks the ovipositor. Simultaneously, the male strokes the dorsolateral portion of the female's abdomen with his forelegs. Receptive females spread their wings, elevate their abdomens and spread their vaginal plates. Prior to mounting the male must lick the vaginal plate area. Intromission occurs after mounting. Non-receptive females repel by decamping and kicking. The male's abdomen pulsates strongly prior to attempts at mounting.

Males court normal females more than three times as much as decapitated ones and inseminate the former at a high level while failing to inseminate any decapitated females. Males approaching decapitated females from the front walk over them with no indication of sexual recognition and no courtship activity takes places in front of such females. These females are usually quiescent. Males approaching from the side pause before walking by such females. Males which approach from the rear and court in that position occasionally circle a female and stand in front before completing the circling movement. This only occurs with males which have been courting for long periods prior to circling. If males have not been courting long and perform the circling movement, they walk off upon reaching the front. Males courting these females commonly do so for

periods up to 12 min before ceasing activity. Attempted mounting is rare and in those cases where it does occur the female falls forward and does not decamp. Females are still but for irregular bouts of fending activity occurring even up to 10 min after initiation of male activity. Males courting decapitated females eventually cease and walk off. In no case does a female give an acceptance response.

Decapitated females of these species give no acceptance responses and both *D. guttifera* and *D. occidentalis* differ in their relative immobility, upon contact with a male, from other quinaria group species (Grossfield, 1970a). *D. occidentalis* males do not attempt to mount. In those few cases where *D. guttifera* males attempt to mount they are faced with the inability of the female to maintain posture.

With *D. guttifera* and perhaps the other species it appears that stroking is an autocatalytic activity wherein contact stimuli serve to increase the male excitation and prolong the courtship. This serves to insure that a male, once courting, will continue. The higher level of excitation of males that have been courting is also seen in their completion of the circling movement. This has also been noted by Spieth (1966).

The value of the C/I ratio (number of courtships (C)/number of inseminations (I)) can serve as an index of the efficiency with which courtships are converted to copulations. The most effective courtship would yield C/I = 1.0, and higher values would indicate departures in efficiency in the direction C > I.

Thus, *D. guttifera* appears to have the most effective courtship with a C/I index of 1.2. *D. occidentalis* and *D. falleni* have indices of 1.4 and 2.85 respectively. Parenthetically, of the three species, *D. guttifera* is the easiest and *D. falleni* the most difficult to maintain under conditions prevailing in the laboratory.

Discussion

Bastock & Manning (1955) suggest that excitatory and inhibitory stimuli given by a female can be pooled to give "effective excitation." Decapitated females clearly have a low value of this component of courtship behavior as evidenced by either the number or the temporal sequence of courtships directed towards them.

Another component, discrimination, implies on the part of both males and females, an ability to distinguish among potential partners. This capability allows females to react by sampling more of a male's courtship or by attempting to discontinue it, and males to react by proceeding with, or breaking off, courtship. High discrimination on the part of females may imply effective repelling of male overtures, but decapitated females, especially *D. occidentalis* and *D. guttifera* show that it is pos-

sible to have high threshold and relatively inefficient rejection capability. An example of discrimination information transfer on the part of males is the use of tapping by males of *D. palustris* (Grossfield, 1972) and *D. simulans* (Spieth, 1966) in deciding not to continue with decapitated foreign females. A similar use of this sensory input can be seen in the use of tapping by males of the virilis group (Spieth, 1951).

These divergent inputs of sensory modalities constitute the extrinsic component of discrimination; the intrinsic component of discrimination can be considered the stimulus recognition pattern responsible for stereotyped behavior (Grossfield, 1970a) or the rigid filtering system responsible for integrating the information. Owing to the existence of discernible point of information transfer, the mode of recognition of specific stimuli appears to offer the best route for dissection of a behavior. The degree of environmental lability of any component depends on its own behavioral architecture as well as whether it is a quantitative (for example, a continuum of excitability) or a qualitative factor (recognition of a specific stimulus). A comparison of the various species studied with respect to decapitation allows an evaluation of the organization of some of these components of courtship behavior.

In a no choice situation, decapitated females of *D. simulans*, *D. pseudoobscura*, or *D. hydei* were not inseminated due to their ability to resist males or the fact that males ignored them (Spieth, 1966). Presenting the males with normal and decapitated females simultaneously did yield a few inseminations of decapitated females. The facilitation of male courtship of decapitated females by the presence of normal females has been discussed elsewhere (Grossfield, 1972).

Males of two of the species studied here, however, do not inseminate decapitated females even in the presence of normal females and in spite of prolonged courtship by the males. This reflects differences in the behavioral architecture of courtship, since the failure to inseminate stems from disparate causes in the two sets of examples. In the species cited in Spieth's observations, the reasons revolved about the nature of visual information in the initiation of courtships while the present study suggests causal factors involving stimuli within the courtship sequence itself.

An example of one kind of behavioral architecture is the fact that no decapitated females of *D. guttifera* are inseminated. Males of this species presumably must see the wing spreading response before they attempt to mount (Grossfield, 1966). Since these females cannot give the response, no inseminations result. This illustrates a pattern where performance of a particular action constitutes a gating point or sign stimulus which cannot be bypassed by any other combination of stimuli (Grossfield, 1968, 1970a).

In contrast to this, *D. melanogaster* males do inseminate decapitated

females in a no choice situation and inseminate significantly more when normal females are also present (Spieth, 1966). *D. melanogaster* is a species capable of bypassing an acceptance response. Significantly, no single or multiple sensory deprivation experiment (Bastock & Manning, 1955; Bastock, 1956; Manning, 1959a; Grossfield, 1968) has succeeded in blocking courtship and copulation in this species; males always receive sufficient stimuli to eventually inseminate a significant proportion of females. Apparently any of a number of different kinds of stimuli are sufficient, as opposed to courtship patterns that at some point are locked-in on a particular stimulus as is that of *D. guttifera.* The organization of *D. melanogaster* behavior consists of a number of internally linked centers each with a fluctuating threshold and linked to the different courtship elements (Bastock & Manning, 1955). In addition, individuals are capable of accumulating a quantity of stimulation until threshold drops (Manning, 1959b). The "rape" situations that Spieth (1966) found with decapitated females of some species may be interpreted in the light of this capability. Stroking in the quinaria group provides an example of an autocatalytic activity capable of lowering thresholds. *D. melanogaster* has a flexible system, permitting wide variance in courtship sequence from one male to the next, and allowing a single organism to respond to a wide variety of courtship situations. Brown (1964) has stated that the *D. melanogaster* type of organization does not hold for *D. pseudoobscura.* The quinaria group species represent another departure from the *D. melanogaster* pattern.

The existence of sign stimuli in the courtship of certain light dependent species suggests that releasing mechanisms must exist as well, and these as discrete points of information transfer might be more amenable to genetic analysis. This is supported by the finding that the ability to mate in darkness appears to be at least under partial genetic control (Grossfield, 1966, 1970b).

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A SPECIALIZATION IN NEST PETIOLE CONSTRUCTION BY QUEENS OF *VESPULA* SPP. (HYMENOPTERA: VESPIDAE)

Robert L. Jeanne

Abstract.—Jeanne, Robert L., Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706.—Queens of *Vespula arenaria* and *V. maculata* coat the petiolar suspension of their nests with a rubbery secretion which permits the young comb to move freely within the envelope. The movement allows the queen to squeeze between the comb and the envelope to reach the top of the comb, even though the space enclosed by the envelope is barely larger than the comb it surrounds. Thus the flexible petiole permits the envelope to surround the comb more closely than would be possible were the comb rigidly attached to the substrate. The advantages of minimizing the envelope diameter at this early stage of colony development are unknown, but probably relate to maximization of the numbers and rate of development of the initial brood. When the first workers emerge in the colony, they make the petiole rigid by buttressing it with carton.

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Social wasps in the family Vespidae are collectively known as "paper wasps" because with few exceptions their nests are constructed of a paper-like carton consisting of fibers of wood or other vegetable material collected by the wasps. It has long been known that as the worker wasps masticate each load of carton material prior to adding it to the nest, they mix in a small amount of labial gland secretion, which hardens and serves to cement the fibers together into the more or less paper-like consistency typical of each species (Janet, 1903). The secretion of the adult labial gland probably has this basic function in all of the 30-odd genera of social wasps. In some, however, the secretion has come to play additional more specialized roles in nest construction. In *Polistes*, *Mischocyttarus*, *Belonogaster*, *Parapolybia* and *Ropalidia* (except the subgenus *Icarielia*) it is used in almost pure form to construct the tough petiole that attaches the nest to its substrate (Jeanne, 1970b). *Pseudochartergus fuscatus* and *P. chartergoides* (Jeanne, 1970a) and *Ropalidia opifex* (van der Vecht, 1962) enclose their nests by cementing together surrounding leaves with large amounts of oral secretion that is probably also produced by the labial gland. *Metapolybia pediculata* leaves numerous small "windows" of the pure secretion in the otherwise opaque envelope of its nest (Rau, 1933).

This note reports on a similar specialized use of what is probably also the labial gland secretion in nest construction by *Vespula* (*Dolichovespula*)

arenaria and *V.* (*D.*) *maculata*. The following observations were made on young colonies of these two species in West Chesterfield, New Hampshire, in 1976. Activities of founding queens inside their nests were made visible by cutting away a tangential section of envelope on one side and closing the opening with window glass. Additional nests in early stages of development were collected for study of the petiole structure.

The initial supporting petiole first constructed by the queen in early summer consists of carton and is correspondingly stiff. This condition persists for several days, until after the first few cells are constructed and provided with eggs. As the comb continues to grow in size, however, the queen begins to coat the petiole with a translucent material of rubbery consistency. In one nest of *V. arenaria* the queen was seen to lick the petiole continuously for a period of more than a minute. It is probably this licking that serves to apply the material.

A nest of *V. arenaria* collected on June 15 and containing 25 cells with half-grown larvae in the oldest cells had a thin coating of the substance on its petiole. Nests of both species collected just prior to emergence of the first workers had a much thicker coating; the coating on such a nest of *V. maculata* was approximately 1 mm thick.

At this stage the petiole is rather flat in cross-section, especially near the middle of its length, where the rubbery coating constitutes much more of the cross-sectional area than does the pulp core it surrounds. The flexible nature of the coating combined with the thinness of the core allows the comb to swing freely from side to side and even to twist to a considerable degree. The material is elastic and if the petiole is pulled it will stretch before breaking and sliding off the pulp core.

In a nest of either species shortly prior to emergence of workers the inner layer of envelope closely surrounds the comb, which may now have grown to comprise 30–60 cells. The only way the large queen can squeeze between the comb and the envelope to reach the top of the comb and the petiole is to swing the comb against the envelope on the opposite side like the clapper of a bell, thus widening the space on her side. The queen also pushes the comb to one side to gain access to the comb's peripheral cells, whose openings face somewhat laterally.

Such a specialized suspension of the comb would not be necessary if the space enclosed by the envelope were larger at this stage of nest development. Thus, it appears that the freely mobile comb is an alternative to constructing a larger envelope. There are at least three advantages to minimizing the diameter of the envelope at this stage of colony development: (1) it permits the queen to maximize the proportion of nesting material devoted to brood cells, thus maximizing the number of worker offspring produced early in the life of the colony; (2) it minimizes the volume of air enclosed by the envelope, thus maximizing the effectiveness of

thermoregulation by the queen; (3) it minimizes the outer surface area of the nest through which heat is lost by radiation.

Whatever function the specialization may serve, it is evidently of value only in the queen nest, for within a day after the first workers emerged in one closely-observed nest of *V. arenaria* they began adding carton to the petiole in the form of radiating, sheet-like buttresses. After three days of such activity the attachment of the comb was so stiffened that the queen and workers had difficulty in squeezing by to reach the top of the comb. Meanwhile, however, the inner layers of the envelope were being removed at an accelerating rate by the increasing numbers of workers. This provided a larger crawl space and made continued movement of the comb unnecessary.

While this modification of the petiole was being made by the workers, they were also beginning construction of the petiole for the second comb. The queen took no part in this and there was no evidence that the petiole of this second comb was ever provided with a flexible coating as was that of the first. All combs of mature nests are rigidly attached by enlarged buttressed petioles of stiff carton. Careful removal of this carton reveals the layer of secretion around the central core of the petiole of the first comb, but not of those below.

Acknowledgments

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THE ANTHOMYIIDAE AND MUSCIDAE OF THE PRESIDENTIAL RANGE IN NEW HAMPSHIRE (DIPTERA)

H. C. Huckett

Abstract.—Huckett, H. C., Long Island Vegetable Research Farm, Cornell University, Riverhead, New York 11901.—A survey of the Anthomyiidae and Muscidae occurring on the upper region of the Presidential Range in New Hampshire was made during the early summer of 1954, 1955, 1956, from bases at the Lakes of the Clouds and at Madison (Maps 1 and 2). The collections of adults included 62 anthomyiid species and 1 subspecies and 117 muscid species and one subspecies out of a total of 5,667 specimens. To this has been added separately a number of specimens in the collections of Mrs. A. T. Slosson, made at the turn of the century, and that I have been able to identify. The names cited in her records as *Coenosia albicornis* and *Aricia vagans* are misapplied. I regard these specimens as belonging respectively to the species *Coenosia* (*Limosia*) *compressa* Stein and *Lasiops albibasalis* (Zetterstedt) new synonymy.

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Introduction

This investigation is the third of a series of studies on the families Anthomyiidae and Muscidae (Diptera) occurring on the upper slopes of the Appalachian Range. The present work was carried out in 1954–1956 on the Presidential Range of mountains in New Hampshire, motivated by the same desire as previously of providing an adequate list of the fauna in view of the apparent increasing menace to the habitat of many of the species, a condition brought about by the requirements for additional trail and camping facilities. Such influences have been fully discussed by Goff, Smith, and others (1976), and by Bliss (1963).

Collections in the southern region of the Range, from Oakes Gulf to the Great Gulf, a distance of approximately 3½ miles, were made during the latter half of June to mid July in 1954 under favorable weather conditions, and also in 1956, when the season proved to be unfavorable owing to the blanket of clouds covering the Range, and to the drop in temperatures. The various localities within the area were visited from the A.M.C. hut at the Lakes of the Clouds.

I have received a valuable collection of specimens taken in this region by various members of the Entomology Institute at Ottawa through the courtesy of Dr. J. R. Vockeroth, and to them I am deeply indebted. Among this material are the notable records of *Delia linearis* (Stein) and *Spilogona argentiventris* (Malloch) from the summit of Mt. Washington. Also through-

out the years I have been granted the privilege and opportunity of consulting the collections of anthomyiid and muscid flies at the United States National Museum, the Museum of Comparative Zoology (MCZ) at Cambridge, and of the Boston Society of Natural History. To the curators, past and present, in charge of these collections at the various institutions I am deeply obligated for favors conferred.

I visited the northern sector of the Presidential Range, from Mt. Adams to Mt. Madison, a distance of approximately 3¼ miles, in late June to mid July of 1955 under favorable weather conditions. The various localities were reached from the A.M.C. hut at Madison, situated slightly below the col that separates Mt. Adams from Mt. Madison.[1]

Previous Records

References to the anthomyiid and muscid fauna of the Presidential Range are mainly scattered throughout the literature, occurring in articles dealing with subjects of wider scope, or are confined chiefly to records on Mt. Washington itself and the immediate surroundings. Slosson (1895–1902) in her list of insects collected in the alpine region of Mt. Washington records the names of approximately 39 nominal species belonging to the families Anthomyiidae and Muscidae. Many of the specimens were sent to Coquillett at Washington for determination. In the catalog of Diptera in North America (1965) 34 of these names are of species occurring in the nearctic region, 14 of which are placed in synonymy, 4 of names falsely applied, *cunctans* Meigen, *vagans* Fallen, *litorea* Fallen, *carbonella* Zetterstedt and 2 remain unplaced, *albicornis* Meigen, *fuscopunctata* Macquart.

In my visits to the museum at Washington for the purpose of studying the northern muscid fauna of the continent I have been accorded the opportunity of examining some of the specimens that were originally in the collections of Mrs. Slosson. These records I have separately included in the following list for the Presidental Range. Among the materal I have been able to find a female specimen determined by Coquillett as *Coenosia albicornis* Meigen, that I regard as belonging to *Coenosia compressa* Stein, and in addition a male of the same species without Coquillett's handwritten label. Similarly I have found a female specimen determined as *Aricia vagans* Fallen, that in my opinion belongs to *Lasiops albibasalis* (Zetterstedt). Of the remaining names in Slosson's list of alpine species I regard those referring to *urbana*, *pagana*, *uliginosa* and *hispida*, as requiring further confirmation for acceptance. So far as I am aware the identity of *Lispe hispida* Walker is unknown.

Johnson (1925) in his list of the Diptera of New England included the names of 120 nominal species from the White Mountains, of which 32 are cited from the upper slopes of Mt. Washington. To the latter I have arbitrarily added the localities Base Station at 2,600 feet elevation and Half-

way House at 3,840 ft. Many of the names for species have been taken from the Slosson list, or the names have been noted in the synonymy recorded in the catalog of Diptera in North America (loc. cit.). Johnson records in his list that the name *Lasiops cunctans* is misapplied, a claim based on receiving a specimen named *cunctans* from Mrs. Slosson, that belonged to the species *Lasiops innocuus* (Zetterstedt). The name *Mydaea rugia* Walker has been shown by Snyder (1949) to refer to specimens belonging to the species *Mydaea palpalis* Stein.

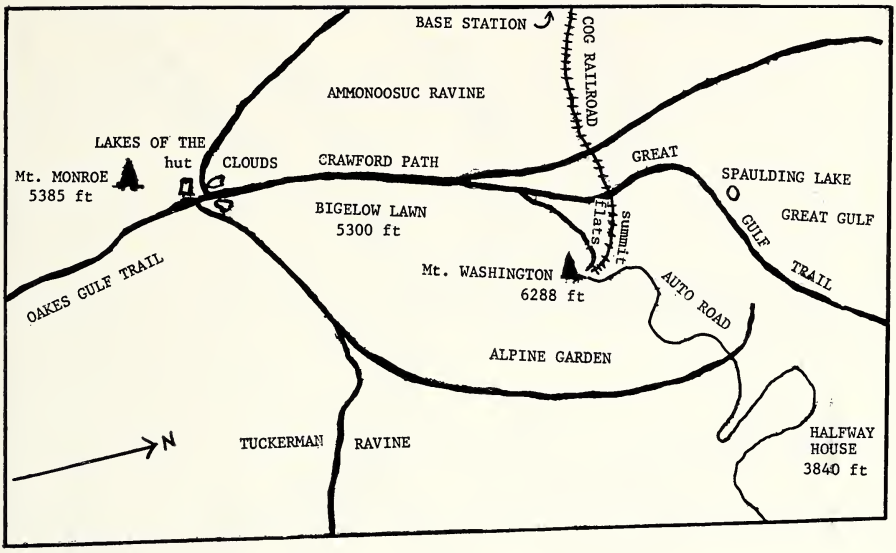
Among what may be considered typographical errors or misunderstanding may be mentioned the following: the name *calophaga* for *calopyga* in the genus *Xenocoenosia*; the name *Macrocoenia* for *Macrocoenosia*; the entry "Mt. Washington (Mrs. Slosson); White Mts. (Morrison)" under *Bithoracochaeta leucoprocta* (Wiedemann). This record is apparently misplaced as indicated by the reference cited in the text, and thus should be transferred to the species *Ophyra leucostoma* (Wiedemann). I remain in doubt as to whether "Mt. Washington" should be a part of the transfer.

Chillcott (1961) in his review of the nearctic species of Fanniinae has included the names of 15 species from the White Mountains in New Hampshire. The presence of *Fannia canicularis* (Linnaeus) and *Fannia scalaris* (Fabricius) is not given owing evidently to their reputed wide occurrence in North America. Eight of the species from the White Mountains are cited as having been taken in the higher regions of the Presidential Range. Of these, seven belong to the genus *Fannia*, namely *abrupta*, *immaculata*, *melanura*, *meridionalis*, *postica*, *sociella*, *spathiophora*, and one to the genus *Coelomyia*, namely *C. subpellucens* (Zetterstedt). All except *canicularis* and *scalaris* are represented in the present survey.

The remaining records pertaining to the anthomyiid and muscid fauna may be found in articles dealing with Diptera of wider geographical range. Among such may be found the contributions of Malloch for the years 1913l, 1920a, 1923a, 1924h, and of Huckett, 1932, 1941, as given in the bibliography to the catalog of Diptera in North America (loc. cit. pp. 1117–1547).

Abbreviations

In order to save space the various locations on the Presidential Range from which specimens were obtained have been assigned a letter, such as A, B, C, and also for each species the number of specimens from all locations have been combined. The locality Mt. Washington (A) has been reserved for species whose specimens are so labelled and without further detail. I have also added separately specimens having the label "In the collections of Mrs. A. T. Slosson" that I have been able to identify, and that are in the collections of the United States National Museum unless otherwise indicated.



Sketch Map 1. The southern region of the Presidential Range showing localities for collecting. Distances from the A.M.C. hut at the Lakes of the Clouds to Oakes Gulf are approximately ½ mile; to Tuckerman Ravine, .75 mile; to Alpine Garden, 1 mile; to summit of Mt. Washington, 1 mile; from Halfway House to summit of Mt. Washington, 4 miles.

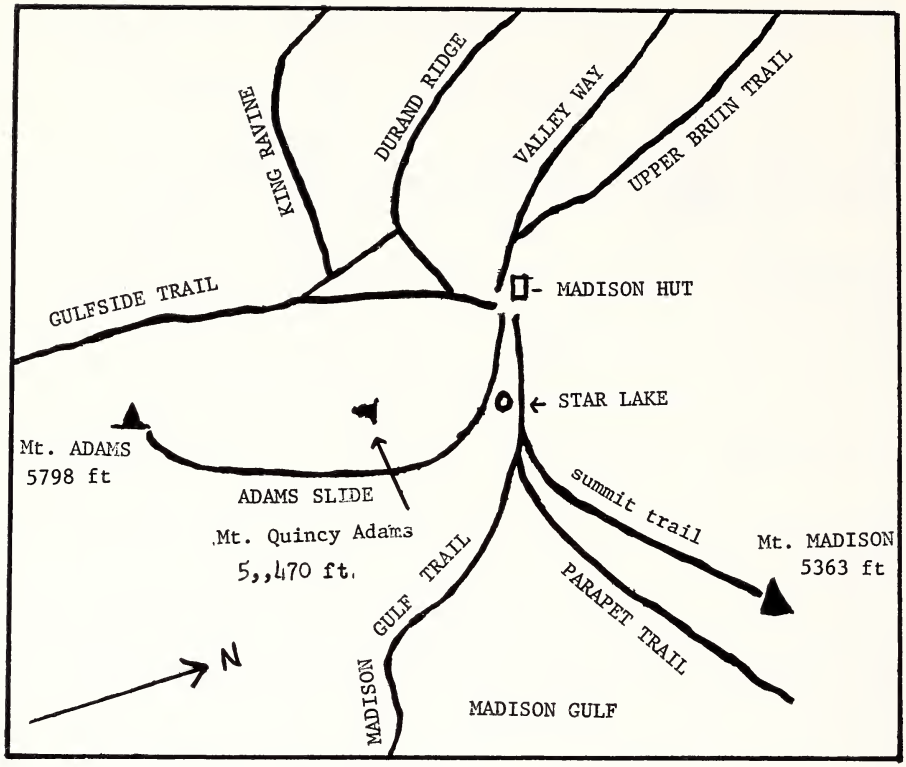
Southern region of the survey.—A, Mt. Washington; B, Base Station, 2,600 ft.; C, Lakes of the Clouds hut, 5,050 ft.; D, Upper Oakes Gulf and trail; E, Upper Ammonoosuc Ravine; F, Crawford Path, 4,500 ft.; G, Bigelow Lawn, 5,200 ft.; H, Upper Tuckerman Ravine; I, Alpine Garden, 4,800 to 5,200 ft.; J, Spaulding Lake, 4,250 ft.; K, Great Gulf to summit flats; L, Halfway House, 3,840 ft.; M, Auto road, 4,000 to 5,500 ft.; N, Summit flats, Mt. Washington; O, Summit of Mt. Washington, 6,288 ft.

Northern region of the survey.—P, Upper Valley Way to Madison hut, 4,825 ft.; Q, Upper Bruin trail; R, Durand Ridge and crossover; S, King Ravine trail; T, Mt. Quincy Adams, 5,470 ft.; U, Star Lake, 4,925 ft.; V, Gulfside trail, Mt. Adams; W, Adams Slide to summit of Mt. Adams, 5,798 ft.; X, Madison Gulf and trail; Y, Parapet trail; Z, Summit trail to Mt. Madison, 5,363 ft.

List of Species and Locality Records

Family Anthomyiidae *Sensu stricto*

Fucellia tergina (Zetterstedt), 3♂, 5♀. C, D, I.
Chirosia pusillans (Huckett), 2♂, 4♀. H, J.
Chirosia stratifrons (Huckett), 1♂, 1♀. G, H.



Sketch Map. 2. The northern region of the Presidential Range showing localities for collecting. Distances from A.M.C. Madison hut to Mt. Madison, .45 mile; to summit of Mt. Adams, .9 mile; to Star Lake, .1 mile; from Randolph to Madison hut by Valley Way trail, 3¼ miles.

Hylemya alcathoe (Walker), 2♂, 2♀. P, Z.
Hylemya latifrons (Schnabl), 5♂, 5♀. C, D, G, I.
Hylemyza partita (Meigen), 3♂, 2♀. C, G, K, J.
Delia alaba (Walker), 10♂, 7♀. C, D, H, I; W, Y.
Delia cupricrus (Walker), 21♂, 1♀. D, I; M, X.
Delia egleformis (Huckett), 57♂, 1♀. P, R, W.
Delia florilega (Zetterstedt), 38♂, 2♀. C, D, H; U, V, W, X.
Delia linearis (Stein), 1♂. O.
Delia platura (Meigen), 266♂, 282 ♀. C, D, E, F, G, H, I–K, N; P, Q, R, S, T, U–X, Y, Z.
Delia pluvialis (Malloch), 1♂. M.
Delia setitarsata (Huckett), 1♀. J.

Delia tarsata (Ringdahl), 496♂, 109♀. A, C, D, E, F, G, H, I, J, K, M; P, S, U, V, W, X, Y.
Delia tarsifimbria (Pandelle), 64♂, 3♀. P, Q, R, S, W, X, Y, Z.
Botanophila anane (Walker) = *Hammomyia setigera* Johannsen (Huckett, 1971), 1♂, 2♀. B.
Pegohylemyia fugax (Meigen), 9♂, 9♀. D, G, H, I, O; R, Q, W, X, Y, Z.
Pegohylemyia hucketti Ringdahl, 2♀. C; Y.
Pegohylemyia obscura (Zetterstedt) = *Hylemyia sericea* Malloch, det. Ackland, new synonymy.[2] 1♂, 1♀. I.
Pegohylemyia profuga (Stein), 7♂, 5♀. C, D, F; Q, R, W, X.
Pegohylemyia relativa Huckett, 5♂, 1♀. Q, R, W, X, Z.
Paregle aestiva (Meigen), 2♂. D, H.
Paregle cinerella (Fallen), 1♀. U.
Paregle radicum (Linnaeus), 12♂, 4♀. E, J, K, N; P, S, X, Y.
Lasiomma octoguttatum (Zetterstedt), 3♂, 2♀. D, M; W, X.
Acrostilpna atricauda (Zetterstedt), 3♂, 6♀. B, G, I; U, Z.
Acrostilpna consobrina (Huckett), 1♂, 1♀. I, L. (2♂, 1♀, Mt. Washington, A. T. Slosson, HCH.)
Acrostilpna flavipennis (Walker) = *Acrostilpna replicata* Huckett, det. 1971. 1♂. J.
Acrostilpna latipennis (Zetterstedt), 9♂. D, J; Z.
Acrostilpna restorata Huckett, 1♂. Q.
Crinurina cuneicornis (Zetterstedt), 13♂, 4♀. C, D, F, G; H, I, K.
Eremomyia pilimana (Ringdahl), 2♂, 5♀. B, G, J, K.
Eremomyioides cylindrica (Stein), 1♂, 5♀. H, I.
Emmesomyia epicalis Malloch, 1♂. J.
Pegomya bicolor (Wiedemann), 1♀. X.
Pegomya frigida (Zetterstedt), 3♂, 3♀. C, I; Q, T, X.
Pegomya fulgens (Meigen), 1♂. P.
Pegomya incisiva Stein, 1♀. Q.
Pegomya labradorensis Malloch, 1♀. N.
Pegomya lipsia (Walker), 3♂, 1♀. D, H.
Pegomya pilosa Stein, 3♂. S, X.
Pegomya rubivora (Coquillett), 1♂. J.
Pegomya tabida (Meigen), 1♂. H.
Pegomya tenera (Zetterstedt), 2♂, 1♀. C, M; S.
Pegomya transgressa (Zetterstedt), 1♂. S.
Pegomya winthemi (Meigen), 1♀. B.
Pegomya zonata (Zetterstedt) = *Musca rufipes* Fallen, *nom. preoc.* (Hennig, 1973), 1♀. L.
Nupedia acutipennis (Malloch), 2♂. E, H.

Nupedia infirma (Meigen), 9♂, 16♀. C, J, K, M, N, O; P, R, V, W, X.
Nupedia nigroscutellata (Stein), 5♂. L; Q.
Nupedia patellans (Pandelle), 9♂, 45♀. J, K; P, R, S, U, W, X, Z.
Pseudonupedia intersecta arctica (Ringdahl), *syn. ssp. arcticola* (Huckett), det. Hennig, 1972 p. 439, 2♀. Q, X.
Hydrophoria alpina Huckett, 6♀. E, I, N. (2♂, 1♀, Mt. Washington, A. T. Slosson, HCH.)
Hydrophoria conica (Wiedemann), 5♂, 18♀. B, D, E, G, H, J, K.
Hydrophoria implicata Huckett, 2♂, 1♀. B, G, J.
Leucophora marylandica (Malloch), 1♂. L.
Paraprosalpia angustitarsis (Malloch), 1♀. C.
Paraprosalpia brunneigena (Schnabl) = *Prosalpia incisa* Ringdahl (Hennig, 1969;11), 3♂. J.
Paraprosalpia conifrons (Zetterstedt), 83♂, 21♀. C, D, H, I, J, K; P, R, T, U, X, Y.
Paraprosalpia littoralis (Malloch), 6♂, 5♀. C, H, I, J; P, X.
Paraprosalpia pilitarsis (Stein), 2♂. J.
Paraprosalpia silvestris (Fallen), 1♂, 1♀. M; V.

Family Muscidae

Schoenomyza dorsalis Loew, 2♂, 12♀. U, X, Y.
Schoenomyza litorella (Fallen), 1♀. B.
Coenosia tigrina (Fabricius), 1♀. D.
Limosia atrata (Walker), 2♂, 19♀. B, C, G, I; Q, T, U, W, Y.
Limosia compressa (Stein) = *Coenosia albicornis* Slosson not Meigen, 1♂, 4♀. L, O; Q. (1♂, 1♀, Mt. Washington, A. T. Slosson.)
Limosia conforma Huckett, 6♂, 6♀. G, N, O; S, U, X, Z.
Limosia errans (Malloch), 1♂, 11♀. G; U, W, Z.
Limosia fuscifrons (Malloch), 1♀. J.
Limosia lata (Walker), 3♂, 3♀. R, W, Z.
Limosia nigrescens (Stein), 1♂, 2♀. G; M.
Limosia toshua Huckett, 1♀. M.
Limosia triseta (Stein), 2♀. O.
Hoplogaster morrisoni Malloch, 1♂, 2♀. S, X.
Hoplogaster octopunctata (Zetterstedt), 15♂, 38♀. C, E, G, I, K.
Neodexiopsis calopyga (Loew), 1♀. N.
Neodexiopsis ovata (Stein), 3♀. O; U.
Macrorchis ausoba (Walker), 10♂, 2♀. C, D, E, G, H, J, K.
Lispocephala aemulata Huckett, 1♀. B.
Lispocephala alma (Meigen), 5♀. H, I, K.
Lispocephala brevitarsis Malloch, 1♀. U.
Lispocephala erythrocera (Robineau-Desvoidy), 1♂, 10♀. D, H.

Lispocephala pallipalpis (Zetterstedt), 5♀. Q, U.
Lispocephala spuria (Zetterstedt)[3] = *Lispocephala vitripennis* Ringdahl (Collin, 1963; 280), 1♂, 2♀. D, J, M.
Lispocephala varians Malloch, 3♀. D, I.
Lispocephala verna (Fabricius), 1♀. J.
Pentacricia aldrichii Stein, 1♀. M.
Lispe albitarsis Stein, 1♀. J.
Lispe cotidiana Snyder, 3♀. G, J; X.
Spilogona acuticornis (Malloch), 1♂. L.
Spilogona alticola (Malloch), 19♂, 47♀. B, C–G, H, I, J, K; P, Q, S, V, X. (1♀, Mt. Washington, A. T. Slosson, allotype MCZ.)
Spilogona arctica (Zetterstedt), 30♂, 18♀. A, C, D, F, H, I, L, M; P, Q, R, S, U, V, W, X, Y, Z.
Spilogona argenticeps Malloch, 42♂, 11♀. H, I; P, Q, S, T, V, X.
Spilogona argentiventris (Malloch), 1♀. O.
Spilogona baltica (Ringdahl), 1♂. D.
Spilogona caroli (Malloch), 10♂, 16♀. D, H, I; Q, V, X, Z.
Spilogona forticula Huckett, 4♂, 1♀. V, X.
Spilogona gibsoni (Malloch), 88♂, 45♀. B, C, H, J, K, M, N; Q, S, T, U, V, W–Z. (1♂, 1♀, Mt. Washington, A. T. Slosson.)
Spilogona hypopygialis Huckett, 4♂. H, I.
Spilogona limnophorina (Stein), 3♂. C, N, O.
Spilogona magnipunctata (Malloch), 185♂, 87♀. C, D, E, G, H, I, J; Q, S, T, U, V–Z.
Spilogona monacantha Collin, 65♂, 157♀. G, H; P, Q, R, S, T, U, V, W, X, Y, Z. (1♀, Mt. Washington, A. T. Slosson.)
Spilogona nigriventris (Zetterstedt), 2♂, 1♀. C, H, L.
Spilogona novemmaculata (Zetterstedt), 2♂, 3♀. D, H.
Spilogona placida Huckett, 1♂, 3♀. J, H.
Spilogona semiglobosa (Ringdahl), 4♂, 5♀, Q, T, V, X, Y, Z.
Spilogona setilamellata Huckett, 3♂, 6♀. D, H, I; X.
Spilogona sororcula (Zetterstedt), 5♂, 4♀. B, D, E, H; X.
Spilogona suspecta (Malloch), 7♂, 4♀. C, I; M, N, X, Z.
Spilogona trigonata (Zetterstedt), 6♂. C, G, J.
Spilogona trigonifera (Zetterstedt), 20♂, 7♀. D, E, F, G, H, I, K, M, O; Q, R, W.
Helina consimilata Malloch, 1♀. C.
Helina maculipennis (Zetterstedt), 5♂, 9♀. A, C, D, I; P, Q, S. (1♂, Mt. Washington, A. T. Slosson.)
Helina obscurata (Meigen), 3♀. Q, S, U.
Helina obscurinervis (Stein), 3♀. B, C, J.
Helina pectinata (Johannsen), 2♂, 3♀. B, D, J.

Helina rothi Ringdahl, 9♂, 21♀. B, C, D, E, G, H, I, J, K.
Quadrularia annosa (Zetterstedt), 9♂, 19♀. D, E, G, H, I, J, K. (2♀, Mt. Washington, A. T. Slosson.)
Quadrularia laetifica (Robineau-Desvoidy), 83♂, 80♀. B, C, D, E, G, H, I, J, K; P, Q, R, T, U–Z.
Hebecnema affinis Malloch, 4♂. E, H, K.
Hebecnema vespertina (Fallen), 7♂, 3♀. B, D, E, H; X.
Mydaea brevipilosa Malloch, 3♀. C, D, H.
Mydaea discimana Malloch, 3♀. I; X, Y.
Mydaea electa (Zetterstedt), 2♀. C, K.
Mydaea furtiva Stein, 3♀. C, H, I.
Mydaea neglecta Malloch, 3♀. R, X.
Mydaea nubila Stein, 33♂, 26♀. P, Q, R, S, T, W, X.
Mydaea obscurella Malloch, 3♀. D; V, W.
Mydaea occidentalis Malloch, 1♂. B.
Mydaea palpalis Stein, 56♂, 11♀. B, C, D, E, G, H, I, J, K, L.
Myospila meditabunda (Fabricius), 3♂, 13♀. C, D, H, I; P, R, S, Y.
Fannia abrupta Malloch, 25♂, 14♀. A, B, C, H, J; P, R, S, U, V, W, X.
Fannia aethiops Malloch, 1♂. H.
Fannia bradorei Chillcott?, 1♀. A.
Fannia brevipalpis Chillcott, 1♀. P.
Fannia ciliatissima Chillcott, 2♀. E; S.
Fannia fuscula (Fallen), 1♂. J.
Fannia immaculata Malloch, 2♂. W, Z.
Fannia melanura Chillcott, 1♂, 4♀. A; U, X.
Fannia meridionalis Chillcott, 1♀. A.
Fannia meridionalis Chillcott, 1♂. A.
Fannia metallipennis (Zetterstedt), 2♂, 8♀. L; P, R, S, U, W.
Fannia postica (Stein), 4♂, 13♀. H, I; Q, R, S, T, U, W, Y, Z.
Fannia rondanii (Strobl), 1♂, 8♀. J, L; U.
Fannia sociella (Zetterstedt), 32♂, 16♀. A, C, E, J, M; P, Q, S, U, W, X.
Fannia spathiophora Malloch, 1♂, 71♀. S, U, W.
Coelomyia subpellucens (Zetterstedt), 69♂, 39♀. A, C, D, E, F, G, H, I, J, K; P, Q, R, S, T, U, W, X.
Piezura graminicola (Zetterstedt), 1♀. X.
Azelia cilipes (Haliday), 2♀. D; Z.
Hydrotaea militaris (Meigen), 13♂, 138♀. B, C, D–H, I, J, K; P, Q, R, S, T–X, Y, Z.
Hydrotaea pilipes Stein, 1♂. B.
Hydrotaea pilitibia Stein, 34♀. J, K; P, Q, R, S, T, V, W, X.
Hydrotaea spinifemorata Huckett, 1♀. C.
Lasiops albibasalis (Zetterstedt) = *Aricia vagans* Coquillett not Fallen, ♀.

11♂, 16♀. B, C, D, G, N; P, R, S, T, V, W, X. (1♂, 3♀, Mt. Washington, A. T. Slosson.)

Lasiops furcatus (Zetterstedt), 2♂, 3♀. G, H, J, K.

Lasiops hirtulus (Zetterstedt), 197♂, 218♀. C, D, E, F–I, L, M, N, O; R, S, U, V–Y, Z. (2♂, 1♀, Mt. Washington, A. T. Slosson.)

Lasiops innocuus (Zetterstedt), 14♂, 69♀. C, D, I, M, N; P, Q, R, S, T, U, V, W, X, Y Z.

Lasiops rufisquama (Schnabl), 1♀. Q.

Lasiops septentrionalis (Stein), 54♂, 85♀. B, C, D, F, H, I, M; P, R, T, U, V, W, X, Y. (2♂, Mt. Washington, A. T. Slosson.)

Lasiops spiniger (Stein), 180♂, 481♀. B, C, D, E, F–L, M, N, O; P, Q, R, S–W, X, Y, Z. (2♂, 5♀, Mt. Washington, A. T. Slosson.)

Alloeostylus diaphanus (Wiedemann), 4♂, 8♀. B, L; P, Q, X.

Phaonia apicata Johannsen, 1♂, 3♀. P, R, U, Y.

Phaonia brevispina Malloch, 1♀. O.

Phaonia cauta Huckett, 2♀. D; T.

Phaonia curvipes (Stein), 3♀. D.

Phaonia errans (Meigen), 1♂, 5♀. D; P, Q, T, X.

Phaonia errans completa Malloch, 1♂. B.

Phaonia fraterna Malloch, 1♂. G.

Phaonia pratensis (Robineau-Desvoidy) = *Musca laeta* Fallen, *nom. preoc.* (Hennig, 1963; 857), 1♂. I.

Phaonia protuberans Malloch, 249♂, 228♀. A, B, C, D–I, J, K, L; P, R, S, U, V, W, X, Y. (1 ♀, Mt. Washington, A. T. Slosson, HCH.)

Phaonia serva (Meigen), 1♂, 5♀. D, F, I, L; Z.

Phaonia subfuscinervis (Zetterstedt), 4♂, 18♀. C, D, H, I.

Phaonia tipulivora Malloch, 1♂, 1♀. H, L.

Phaonia winnemanae Malloch, 1♀. Mt. Washington, A. T. Slosson, (HCH).

Lophosceles cinereiventris (Zetterstedt), 13♂, 15♀. C, E, G, H, K, N; P, S, U, W, X.

Lophosceles frenatus (Holmgren), 25♂, 4♀. A, D; P, Q, T, X, Y.

Mesembrina latreillii Robineau-Desvoidy, 18♀. C, D, F; P, R, W, X.

Morellia micans (Macquart), 1♀. D.

Musca domestica Linnaeus, 2♂, 1♀. C, I.

Stomoxys calcitrans (Linnaeus), 2♀. C.

Summary

In both families the species collected indicated a strong northerly thermophygic affinity (Bradley, 1956). Twenty genera of Anthomyiidae and 28 of Muscidae were recognized, including the genera *Eremomyioides* and *Pentacricia* known only to occur in North America, and the neotropical genus *Neodexiopsis* (Pont, 1972).

The family Anthomyiidae was represented by 38 species that occur in the palearctic and nearctic regions, and 24 species and one subspecies known only from the nearctic. The following species occurring in both regions were found to be most numerous, *Delia platura* (Meigen), *D. tarsata* (Ringdahl), *D. tarsifimbria* (Pandelle), *D. florilega* (Zetterstedt), *Nupedia patellans* (Pandelle), *Paraprosalpia conifrons* (Zetterstedt). The species *Delia egleformis* (Huckett), known only from the nearctic region, numbered 56 specimens taken in three localities. Anthomyiid species that are known to have extended their range to the coasts of Greenland were *Fucellia tergina* (Zetterstedt), *Delia platura* (Meigen), *Pegohylemyia profuga* (Stein), *Paregle cinerella* (Fallen), *Paregle radicum* (Linnaeus), *Lasiomma octoguttatum* (Zetterstedt), *Pegomya pilosa* Stein, *Pegomya tenera* (Zetterstedt), *Pegomya zonata* (Zetterstedt), and the subspecies *Pseudonupedia intersecta arctica* (Ringdahl). Forty-two of the species were collected in succeeding years on Mt. Katahdin in central Maine, and 27 in the Great Smoky Mountains and on Mt. Mitchell in North Carolina (Huckett, 1972, 1974).

In the family Muscidae 117 species and one subspecies were recognized, of which 57 are known to occur in the palearctic and nearctic regions, and 60 species and one subspecies restricted to the nearctic. Species occurring in both regions and found to be most numerous included *Hoplogaster octopunctata* (Zetterstedt), *Spilogona arctica* (Zetterstedt), *Spilogona triangulifera* (Zetterstedt), *Quadrularia laetifica* (Robineau-Desvoidy), *Mydaea palpalis* Stein, *Fannia sociella* (Zetterstedt), *Fannia spathiophora* Malloch, *Coelomyia subpellucens* (Zetterstedt), *Hydrotaea militaris* (Meigen), *Hydrotaea pilitibia* (Stein), *Lasiops albibasalis* (Zetterstedt), *L. hirtulus* (Zetterstedt), *L. innocuus* (Zetterstedt), *L. spiniger* (Stein), *Lophosceles cinereiventris* (Zetterstedt), *L. frenatus* (Holmgren). Muscid species occurring only in the nearctic region and found to be more numerous included *Spilogona alticola* (Malloch), *S. argenticeps* Malloch, *S. gibsoni* (Malloch), *S. magnipunctata* (Malloch), *S. monacantha* Collin, *Mydaea nubila* Stein, *Fannia abrupta* Malloch, *Lasiops septentrionalis* (Stein), *Phaonia protuberans* Malloch. The following species are also recorded from the coasts of Greenland, *Spilogona arctica* (Zetterstedt), *S. baltica* (Ringdahl), *S. monacantha* Collin, *S. semiglobosa* (Ringdahl), *S. trigonifera* (Zetterstedt), *Lophosceles frenatus* (Holmgren), *Musca domestica* Linnaeus. Seventy-six of the species collected on the Presidential Range were also taken on Mt. Katahdin, and 50 in the Great Smoky Mountains and on Mt. Mitchell in North Carolina.

The occurrence of a single specimen of *Spilogona argentiventris* (Malloch) on the summit of Mt. Washington is noteworthy for the departure from the pattern of its known distribution in western North America.

Names of Collectors

Becker, E. C.
Blanton, F. S.
Dimmock, G.
Huckett, H. C.
Johnson, C. W.
Mason, W. R. M.
Melander, A. L.
Morrison, H. K.
Morse, A. P.
Munroe, E. G.
Reiff, W.
Shewell, G. E.
Slosson, A. T.
Townsend, C. H. T.
Vockeroth, J. R.
Walley, G. S.

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Footnotes

[1] The length of the Range from Mt. Monroe in the south to Mt. Madison in the north is roughly 7½ miles by trail. Mt. Washington, located slightly south of the various peaks at midway, is situated at 71°18'W, and 44°16'N.

[2] Mr. D. M. Ackland has made an examination of the genitalia of two males of *Pegohylemyia sericea* (Malloch) taken respectively at Savonoski, Alaska, and Mt. Katahdin, Maine, with that of *Pegohylemyia obscura* (Zetterstedt) found in Scotland, and has concluded there were virtually no specific differences.

[3] *Lispocephala spuria* (Zetterstedt) was incorrectly referred to as *surda* in my remarks concerning *Lispocephala aemulata* (Huckett, 1972; 231).

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BIONOMICS OF THE AQUATIC MOTH, *ACENTROPUS NIVEUS* (OLIVIER),[1] A POTENTIAL BIOLOGICAL CONTROL AGENT FOR EURASIAN WATERMILFOIL[2] AND HYDRILLA[3]

S. W. T. Batra

Abstract.—Batra, S. W. T., Beneficial Insect Introduction Laboratory IIBIII, Agr. Res. Serv., USDA, Beltsville, Maryland 20705.—Larvae of *Acentropus niveus* (Olivier) on watermilfoil in Lake St. Lawrence, N.Y. overwintered in water-filled cocoon-like hibernacula attached to host propagules. Feeding from newly constructed summer shelters on fresh plant growth commenced in June, they produced a single generation of short lived rudimentary-winged aquatic females and winged males which reproduced in July–September. After some feeding, the resulting small larvae entered hibernation in October. In the laboratory, larvae fed on *Myriophyllum spicatum* L., *M. spicatum* var. *exalbescens* (Fernald) Jepson, *Hydrilla verticillata* (L.f.) Royle, *Elodea canadensis* Michx. and *Ceratophyllum* sp. Since diapause apparently is caused by low water temperature rather than by short daylength, this insect may adapt to Florida conditions for possible *Hydrilla* and *Myriophyllum* control. Behavioral details are given, damage to host plants is evaluated and additional host-specificity testing is recommended.

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Introduction

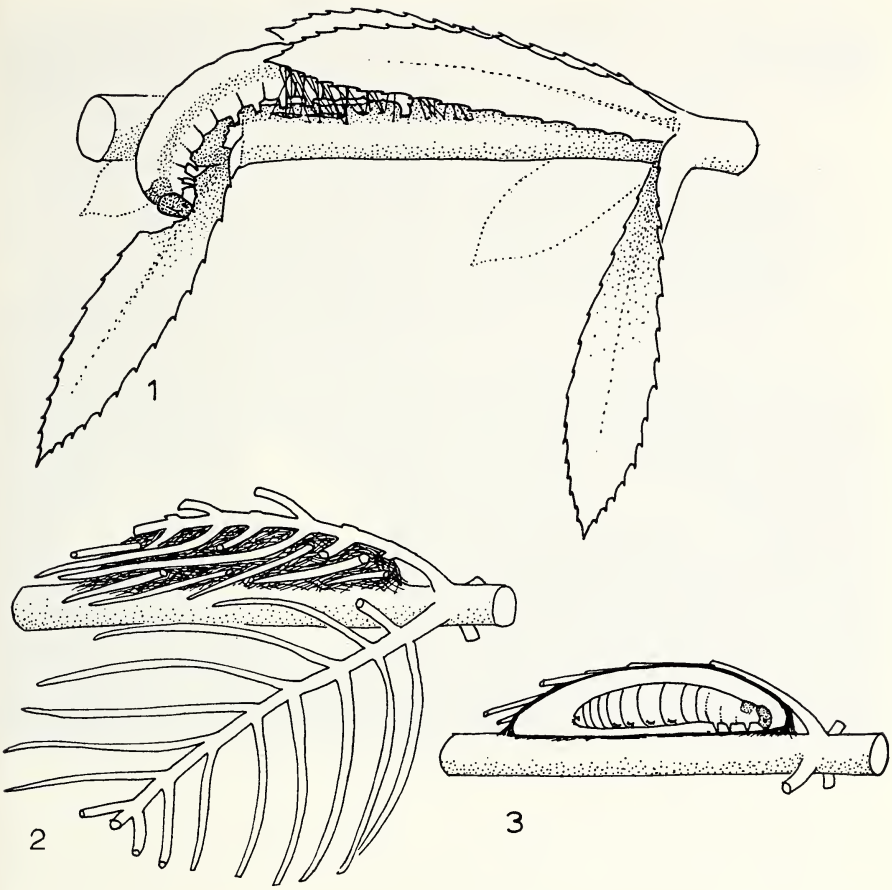
Eurasian watermilfoil *(Myriophyllum spicatum* L.), a submersed aquatic perennial, was first collected in North America (in Chesapeake Bay) in 1902 (Nichols, 1975). Introduced from Europe, it has become a troublesome weed only during the past 20 years, interfering with fishing, causing silting of shellfish beds, hindering navigation and water sports, clogging water intakes, and providing mosquito breeding sites, with consequent depression of property values (Smith et al., 1967; Holm et al., 1969; Spencer and Lekić, 1974). It occupies over 10,000 hectares in the Tennessee Valley Authority reservoirs (Smith et al., 1967), 680 ha in Florida (Blackburn and Weldon, 1967; Spencer and Lekić, 1974); and smaller areas are infested in 20 other states (Nichols, 1975). In the Chesapeake Bay (Maryland), Eurasian watermilfoil occupied 81,000 ha by the early 1950's (Spencer and Lekić, 1974); however, it suddenly declined there by 95% after 1966. This decline has been attributed to algal blooms or pathogens (Bayley et al., 1968) and to increased water turbidity (Southwick and Pine, 1975). Watermilfoil is also able to propagate explosively, for example, in Currituck Sound (North

Carolina), where in one year it extended its range from about 1,600 ha to some 30,000 ha (Nichols, 1975). Axillary vegetative buds and fragmentation of stems are the primary means of reproduction, although the seeds may be carried for longer distances. A 5 cm stem fragment may root and grow 1.5 m in one season; in the second year multiple stems arising from the rooted base may reach a length of 5 m (Smith et al., 1967). It grows well at pH values between 5.8–9.7 and tolerates brackish water (to 15 ppt salt or 40% sea water; Anderson et al., 1965).

Although it is occasionally eaten by waterfowl (Martin and Uhler, 1951) and it shelters small aquatic organisms (Krecker, 1939), Eurasian watermilfoil is generally considered a noxious weed. Periodic lowering of the water table is the most effective control measure, but mechanical harvesting and herbicides are also used (Smith et al., 1967). Due to the cost, impracticality, impermanence or hazardous nature of these methods, biological control agents relatively specific to *M. spicatum* are being sought in Eurasia (Lekić, 1970a, b; Lekić and Mihajlović, 1970; Baloch et al., 1972; Spencer and Lekić, 1974). One of the more promising insects is a European nymphuline moth, *Parapoynx stratiotata* L. (Lekić, 1970a), under study by the USDA-ARS for possible use in watermilfoil control in North America (N. R. Spencer, pers. comm.). Another is *Acentropus niveus* (Olivier) which is a possible biological control agent for watermilfoil in Florida. Studies relating to its potential use were begun in 1975.

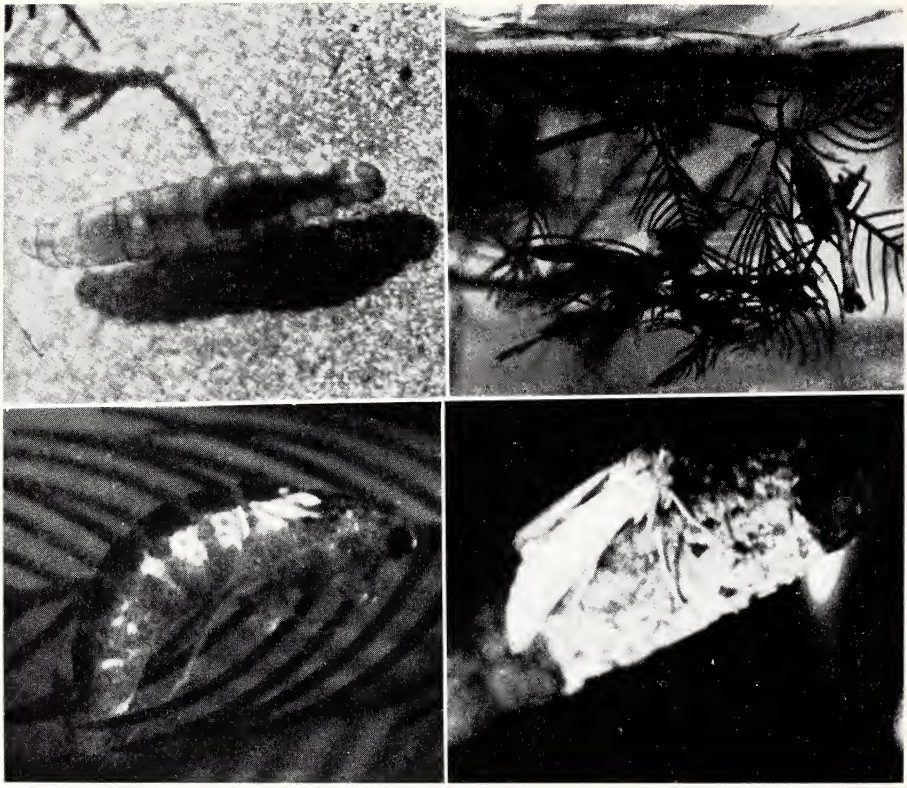
The life history and morphology of *A. niveus*, a univoltine schoenobiine moth, were intensively studied in Europe by Ritsema (1878), Nigmann (1908) and Berg (1942); many details, therefore, will not be repeated here. In Europe it occurs from Scandinavia to the Caspian Sea in fresh or brackish water (Hannemann, 1967). It was first collected in North America in 1927 at Montreal (Sheppard, 1945). For the next 20 years, it was repeatedly and sometimes abundantly found in the St. Lawrence River and its tributaries, and in Lakes Ontario and Erie (Judd, 1950). By 1952 it was in Massachusetts (Treat, 1954; 1955), and there are specimens taken in 1963 at Middleton, Wisconsin, in the United States National Museum. This seems to be an accidentally introduced species that is now rapidly extending its range (also see Lange, 1956).

Acentropus niveus is an unusual moth in several ways: (1) the eggs, some adults and caterpillars are strictly aquatic; (2) larvae lack gills and the rudimentary spiracles are closed; (3) special hibernacula are made by the overwintering larvae; (4) the pupa obtains oxygen through spiracles, which is released into the cocoon from holes made in the aerenchyma of the host plant to which it is attached; (5) some females are fully winged but others from the same population may have rudimentary wings; and (6) the rudimentary-winged females rely on plastron respiration and swim by means of hair brushes on the legs.



Figs. 1–3. Larvae of *Acentropus niveus*. 1. Larva reaching from temporary feeding shelter to feed on *Hydrilla* leaf. 2. Hibernaculum on *Myriophyllum* stem. 3. Longitudinal section of hibernaculum, showing contracted diapausing larva.

Adult *A. niveus* are nocturnally active, do not feed and usually live only about 24 hours. Winged females and males are occasionally collected at lights far from water (Treat, 1954; 1955), and this form evidently is responsible for dispersal to new habitats. Usually males (Fig. 7) fly just above the water surface searching for the uplifted abdomens of receptive, fully aquatic, rudimentary-winged females (Fig. 6). Soon after brief copulation at the water surface, some 115–250 yellow eggs are laid in bands or masses on submerged vegetation. After 12–13 days at 18–20°C (Berg, 1942), the eggs hatch and the first instar larvae bore into stems of host plants. The later 3 instars construct a series of temporary external



Figs. 4–7. Living developmental stages of *Acentropus niveus* (not to same scale). 4. Larva crawling freely through water; the dark gut contents are clearly visible. 5. Larval feeding shelters on *Myriophyllum*. 6. Vestigial-winged female in water. The bright patches are caused by reflection from the air film trapped among the body scales. 7. Male in characteristic resting position near the water surface on protruding *Myriophyllum* stem. Note extended maxillary palpi.

summer shelters of silk and bits of leaves from which they feed for about 5 weeks (Figs. 1, 5). They periodically leave these shelters and crawl freely about (or occasionally carry detached shelters) while spinning a silken thread (Fig. 4). The larval stage, which overwinters, lasts about 10.5 months; the pupal stage lasts about 25 days at 20–22°C (Nigmann, 1908).

In Europe, larvae have been collected or reared from *M. spicatum* L.; *Elodea canadensis* Michx., *Potamogeton crispus* L., *P. perfoliatus* L., *Ceratophyllum demersum* L. and *Trapa natans* L. (Ritsema, 1878; Nigmann, 1908; Berg, 1942). In North America, they were found on *C. demersum* and *Elatine triandra* Schkuhr (Judd, 1950; Treat, 1955). Additional North American hosts reported here are *Elodea canadensis* Michx., *M. spicatum*

var. *exalbescens* (Fernald) Jepson, *M. spicatum*, and in the laboratory they were reared on *Hydrilla verticillata* (L.f.) Royle, another major introduced aquatic weed pest in Florida.

Field Studies

A population of *A. niveus* was studied at the St. Lawrence River near Massena, N.Y. (at Lake St. Lawrence, near Long Sault Dam). Larvae were feeding on *M. spicatum* var. *exalbescens* that was growing densely in a shallow freshwater cove near Barnhart Marina (Robert Moses State Park).

The life cycle in the St. Lawrence River differs slightly from that in Europe (see Berg, 1942; Nigmann, 1908). On 16 June 1976, the watermilfoil was not visible at the surface of the cold, murky water (18°C, 15 cm below the surface, 15°C at 2 m depth). Medium-sized to large overwintered larvae were feeding on young axillary shoots (turions) springing from short, rooting broken bits of old watermilfoil stems (propagules), that were covered with silt and filamentous algae and were lying on the mucky bottom (at 2 m). A random sample of 20 such propagules (mean length 10.6 cm; range 2.5–28.0 cm), with a mean 19.5 (4.0–56.0) leaves, bore $\bar{x}$ 2.5 (0–10) larval shelters. Some of these larvae began to pupate within ten days in the laboratory and an adult male emerged July 7; but no cocoons or adults were found in the field. Adults have been collected as early as June 14 at Lake Erie (Judd, 1950), and in Europe (Netherlands and Germany) they begin to appear in late May (Ritsema, 1878; Nigmann, 1908). According to Berg (1942), larvae break diapause and begin feeding at 12–14°C. This water temperature was reached by mid-May at Esrom Lake, Denmark. When adults first appeared there in late June, the water temperature had reached 21°C. In Lake St. Lawrence, the water reached 12–14°C about three weeks later, by June 1, and 21°C on August 1, a month later than at Esrom Lake, which would explain the relative delay in the appearance of adult *A. niveus* at Lake St. Lawrence.

By 21 July 1976, the water temperature was 20°C at 15 cm below the surface and 18°C at 2 m depth at Lake St. Lawrence. The watermilfoil propagules had rooted and grown rapidly to a length of about 1.5 m but the plants had not quite reached the surface. Larvae and pupae were collected, but adults were not seen, although some emerged after a few days in the laboratory.

By 5 August (1975), the 2–2.5 m long strands of watermilfoil had reached the surface. Numerous *A. niveus* males were resting on the emergent flowering spikes. Larvae and pupae were exclusively on the topmost 5–25 cm of the watermilfoil stems, among the youngest leaves and in a relatively warm zone of sunlit surface water (30°C at 15 cm). The plants formed dense stands in water 1–3 m deep. The matted, floating apices shaded the

senescent, marl and silt covered lower stems and old leaves in cooler (21°C) water. The distribution of the insects was uneven; for instance, a sample of the upper 30 cm of 50 watermilfoil stems from one location yielded 10 pupae, but a similar sample taken 30 m distant contained only one pupa. This may be the result of restricted egg dispersal by the rudimentary-winged females. Winged females were not found in 1975 or 1976 at Lake St. Lawrence, although they were common in Lake Erie (Judd, 1950) and Massachusetts (Treat, 1955). Males spent the day resting 0.5–1.0 cm above the water surface on protruding watermilfoil stems or flowering spikes (Fig. 7). At dusk and during the night, they flew just above the water surface, skittering in circles for about 30–60 sec, alternating with rest periods of several minutes.

By 17 September 1976, most plants were no longer blooming, and the water temperature was 19°C at 15 cm and 18°C at 2 m depth. Adult *A. niveus* were still emerging and young larvae 2–4 mm long were eating leaves near the surface. Eighteen of a random sample of 37 entire watermilfoil plants each bore 1–3 larval or pupal shelters. Twelve of the larvae were on leaves, and 6 (and all pupae) were on stems. Distribution per stem was as follows: uppermost 2 cm, 7 larvae; next 2–4 cm, 9 larvae; 4–6 cm, 1 larva; 7–17 cm, 1 pupa; 18 cm, 1 larva; 25 cm, 1 pupa; below 25 cm, no *A. niveus*. No mature larvae were found and the pupae were evidently the last of the season.

The field site was visited for the final time on 14 October 1976, during a snowstorm. Although the plants still reached the surface, the senescent, fragile stems were beginning to fragment, partly as a result of rough waves. Mean water temperature was 13°C. A random sample of 37 apical 1 m lengths of watermilfoil yielded 22 shelters of 3–4 mm long larvae; no pupae or larger larvae were found. Most of the shelters were on main stems but some were on leaves or overwintering buds. These previously undescribed shelters (hibernacula) were firmly constructed of thick, tough layers of brownish silk and watermilfoil leaflets (Figs. 2, 3). They resembled cocoons rather than the flimsy, temporary summer feeding shelters (Fig. 1). However, unlike the air filled cocoons, they were filled with water. The hibernating larvae were contracted, of a grayish-yellow translucent color, and had empty guts and air-filled tracheae. Unlike feeding larvae, they were unresponsive to light or touch. Evidently these diapausing larvae survive freezing because the water level at the study area is 2–3 m lower in winter and the water freezes to a depth of 1–6 m, which would include the watermilfoil beds.

Laboratory Studies

Larvae and pupae from Lake St. Lawrence were established in a rearing room at Beltsville, Md. Unless otherwise stated, material was kept

in fresh water in a single 20 gal (72.7 liter) aquarium at 18–27°C with a long day length schedule (16 h L: 8 h D). Several species of food plants were provided, primarily *M. spicatum* var. *exalbescens* (eaten), but also at times additionally *M. spicatum* from the Chesapeake Bay (eaten), *Hydrilla verticillata* (eaten), *Elodea canadensis* (eaten), *Ceratophyllum* sp. (eaten), *Myriophyllum brasiliense* Cambess. (not eaten), *Azolla* sp. (not eaten), *Lemna* sp. (not eaten), *Spirodela* sp. (not eaten), *Salvinia* sp. (not eaten), *Pistia stratiotes* L. (not eaten), *Alternanthera philoxeroides* (Mart.) Griseb. (not eaten), *Eichhornia crassipes* (Mart.) Solms (not eaten), and filamentous algae (not eaten). The larvae readily transferred to and ate *Hydrilla verticillata* even when *M. spicatum* was available. Development to the adult stage and egg production on *Hydrilla* appeared normal.

Feeding larvae damaged the watermilfoil by girdling the leaves or stems and by eating leaflets. When 5 large (8–10 mm) larvae were each kept on a 10 cm strand of watermilfoil in petri dishes for 8 days at 23°C, they girdled, broke off and dropped a mean of 15 (range 8–23) entire leaves and also $\bar{x}$ 101 (range 67–180) leaflets. Many additional leaflets that were eaten rather than dropped were represented by some 1,000 frass pellets per larva; food passed through the entire gut in 1.5 h. One of the five larvae girdled the stem and 1–4 shelters per larva were made. However, the watermilfoil strands elongated by $\bar{x}$ 7 (range 0.5–17.0) cm during this time.

The pale greenish-yellow transparent larvae fed from their shelters until leaves within reach were eaten (Fig. 1). The leaves or leaflets were often drawn by feeding larvae toward the shelters or were girdled. When nearby food was depleted, the larvae left their shelters, usually in the mid-morning, and crawled with a somewhat looping motion (covering 1–2.5 cm per minute) until finding suitable food. A new shelter was made before feeding resumed, but occasionally old shelters were re-entered and used again. Larvae ceased feeding and remained quiescent in shelters for 2 or 3 days before cocoon-spinning in the shelters and pupation. Larvae kept on watermilfoil in brackish water from the Chesapeake Bay near Annapolis, Md., developed normally to adults.

Construction of a summer shelter required 1.5–2.0 h at 23°C. The larva first chewed the stems or leaf rachis, which roughened the surface, permitting secure silk attachment. Stiff leaflets were also partially eaten, which increased flexibility. A silken web was spun (about 18 oscillations per minute) to adjacent leaflets, which were gradually drawn over the larva. Larvae continued to eat and often reversed positions during web construction. Frass was excreted through the open caudal end of the shelter; plant detritus, frass, and snail eggs in the shelter were picked up by the mandibles and dropped outside. Algae-covered leaves or stems were avoided. Air bubbles released from the aerenchyma and caught in the web

were also expelled. Enemies include the planarian, *Dugesia* sp., which ate the eggs and dytiscid larvae that attacked larvae. Larvae were unaffected by guppies sharing the aquarium.

Groups of 7 diapausing larvae in hibernacula on watermilfoil taken from the St. Lawrence River in October were each given one of three treatments: (1) freezing in an outdoor pool for 35 days; (2) maintenance at 25°C in the rearing room aquarium at long (16 h) daylength; (3) maintenance at a 21°C laboratory room aquarium at prevailing 8 h winter daylength. The frozen larvae (treatment 1) broke diapause, made summer shelters and began feeding on the sprouting watermilfoil turions within 20 days after being brought into the rearing room. Those kept without prior freezing in the rearing room (2) or laboratory (3) first broke diapause within 15 days. Evidently diapause is maintained by cool temperature rather than by short daylength. Although the diapausing larvae and the feeding larvae had the same head capsule width (about 0.6 mm), the feeding larvae with distended guts were much longer (6.0–6.5 mm) than the empty, shrunken 3.5 mm larvae in hibernacula (Fig. 3).

Discussion

Acentropus niveus may be of some value as a biological control agent for *Myriophyllum spicatum* and *Hydrilla verticillata* in North America. Multiple-choice and starvation tests must be performed to determine the degree of host-specificity or preference in order to avoid possible damage to valuable aquatic plants. For such testing, numerous insects must be maintained to ensure that enough of the short-lived adults simultaneously emerge for mating. Laboratory studies reported here indicate that this insect may become multivoltine in Florida, since adults emerged sporadically throughout the winter in the rearing room, although there were not enough to mate and produce new generations. The question remains as to why it has not extended its range into southern Europe. Perhaps a potential second generation would have been destroyed by frost in a transition zone, although it may have the ability to survive further south, in the subtropics or tropics. Due to the vigorous growth of the target plants, a dense population of *A. niveus* would be needed to do any significant damage. The breakage of stems by feeding larvae creates new propagules which may actually aid in spreading the plant. The possible combination of *A. niveus* with a plant pathogen introduced through feeding wounds may be worth investigating.

Acknowledgments

I thank Robert D. Conner of the St. Lawrence Power Project for information regarding annual water temperatures, water level fluctuations, and

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Footnotes

[1] Lepidoptera: Pyralidae.

[2] *Myriophyllum spicatum* L. (Haloragidaceae).

[3] *Hydrilla verticillata* (L.f.) Royle (Hydrocharitaceae).

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TECHNIQUES FOR REARING THE ALFALFA BLOTCH LEAFMINER[1 2 3]

R. M. Hendrickson, Jr. and S. E. Barth

Abstract.—Hendrickson, R. M., Jr. and S. E. Barth, Beneficial Insects Research Laboratory, Agric. Res. Serv., USDA, Newark, Delaware, 19713.—Three techniques for rearing the alfalfa blotch leafminer, *Agromyza frontella* (Rondani), were developed. A simple method of rearing the leafminer in a cage on potted alfalfa produced small numbers of flies with a minimum of maintenance time. A second method allowed recovery of puparia (mature larvae drop from the leaflet to pupate in soil) which was useful in obtaining puparia from field-collected alfalfa stems, for some biological studies, and for rearing larval-pupal parasites. A mass rearing method, in which infested plants were laid on their sides so larvae dropped into moist vermiculite, was suited for production of large numbers of flies and efficient use of potted alfalfa. Survival of pupae, the stage during which leafminers may suffer high mortality, was 50–60% for all methods.

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The alfalfa blotch leafminer (ABL), *Agromyza frontella* (Rondani), is a European species first found in the United States in Hampshire Co., Mass., in 1968 (Miller and Jensen, 1970). Since then it has spread through the New England states, north into the Canadian provinces of New Brunswick, Quebec, and Ontario, west to the Ohio-Pennsylvania border, and south into Maryland and eastern West Virginia. The rate of spread is such that appearance throughout the northcentral states is possible in 5–10 years.

Techniques were developed for rearing ABL so as to provide the large numbers needed both as hosts for exotic parasites and for biological studies.

Materials and Methods

All experiments were conducted at 20 ± 1.1°C and 65 ± 5% RH in continuous light. Buffalo alfalfa was used, though any variety is probably adequate. The alfalfa plants were propagated in 12.7 cm (5 in) pots in the greenhouse until they were 25–30 cm tall. Then plants were placed in standard oviposition cages (46 × 33 × 40 cm; covered with 17.7/cm (45/in) saran screen) and exposed to ca. 25 adult ♀ for 24 h, long enough to produce 1 or 2 larvae on most leaflets. Honey was provided as food. An average of 139 third-instar (mature) ABL larvae/potted plant exited from the leaflets and dropped to the soil to pupate.

Greater numbers of flies in the oviposition cage or longer oviposition

periods increased larval mortality because excessive numbers of larvae attempted to develop in a single leaflet. Also, excessive numbers of ABL adults caused large numbers of 'pinholes' (feeding punctures made by the ovipositors of female flies), which obstructed the formation of mines, and caused mortality of leafminer larvae. However, any cage of sufficient size to hold potted alfalfa and any screening fine enough to prevent escape of adult flies would probably be adequate. Very dry or very wet substrate for pupation caused high pupal mortality.

Technique 1.—After exposure in the oviposition cage, the pots of alfalfa were placed as close together as possible in standard laboratory cages. Thus most of the mature larvae dropping from leaflets (about 2 wk after oviposition) fell into pots rather than onto the cage bottom where they would die of desiccation. After all larvae had exited from the leaves, the plants were cut back so there would be some regrowth for feeding when adults emerged. In addition, fresh pots of alfalfa were added to the cages as adult flies emerged. All pots were watered daily.

The percentage survival of ABL pupae reared by this simple technique was determined by caging individual plants in a 25 cm-high plexiglas cylinder, 13 cm OD, with 0.3 cm walls. The top and the 16 ventilation holes (2.5 cm diam) drilled near the bottom of the cylinder were covered with fine organdy. The cylinder prevented larvae from leaving the pot and confined adult flies that later emerged. After all larvae had dropped into the potting mixture, the alfalfa was cut, all leaflets were removed including those which had dropped to the bottom of the pot, and the number of empty mines was counted. The adult flies that emerged were removed from the cylinder daily and counted until no further emergence took place.

Technique 2.—After alfalfa plants were removed from the oviposition cage, they were placed on benches under lights at 20°C. Eclosion and larval maturation required ca. 14 days at this temperature, so at 12 days the alfalfa was cut, and the cut stems were placed on aluminum window screen over a plastic utility tub lined with slightly moistened blotter paper (Fig. 1). (The screen prevented plant material from dropping into the tub and interfering with the collection of puparia.) The larvae emerged from the leaflets, dropped through the screen, and pupated, usually under the blotter paper. The entire unit was kept in a sealed plastic bag to maintain high humidity. However, if large water droplets condensed on the inside of the tub, some of the larvae drowned.

The puparia were lightly affixed to the bottom of the tub or to the blotter paper, but they could be dislodged without injury by washing under a gentle stream of tap water. The water with puparia in it was then poured through a fine mesh screen to isolate the puparia. To avoid desiccation, the puparia were placed in 50 mm-diam tightly-sealed petri dishes with

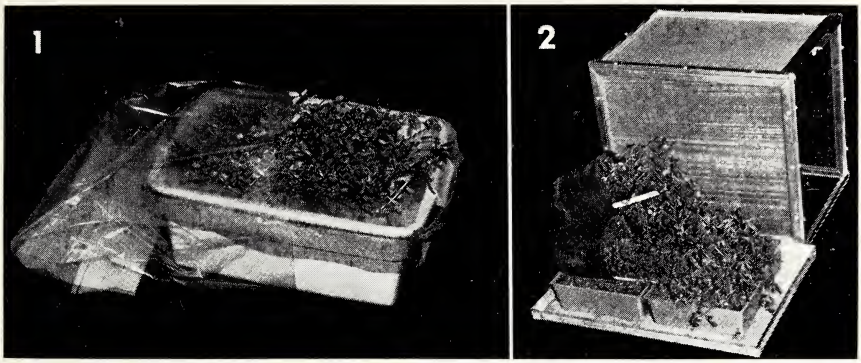

Fig. 1. Puparia recovery technique showing infested, cut alfalfa placed on window screen over plastic utility tub. Larvae drop from the plants and pupate under moistened blotter paper lining bottom of tub. High humidity is maintained by enclosing the unit in a sealed plastic bag.

Fig. 2. Mass rearing technique showing mined alfalfa plants placed on their sides so that larvae emerging from the leaflets fall into the vermiculite to pupate. Cage was removed for photograph.

moistened filter paper on the bottom. The petri dishes were examined and emerging adults removed daily.

Technique 3.—After plants were removed from oviposition cages, they were kept on benches under lights for ca. 12 days. At that time, shortly before larvae dropped from the leaflets, the plants were laid on their side on top of 4 plastic flats (13 × 20 cm) in a standard laboratory cage (Fig. 2). Each flat was filled with moistened sterilized vermiculite. Thus, the larvae dropped into the vermiculite rather than into the alfalfa pot itself. Since all the larvae developing on a given alfalfa plant were the same age within 24 h, they completed larval development as a group and emerged from the leaflets within a period of 2 or 3 days. The plants were then removed, and additional plants infested with 3rd-instar (mature) larvae were placed in the cage. Completion of the pupal stage required ca. 3 weeks, so at the end of this period the flats filled with vermiculite were placed in cages for adult emergence.

Survival of ABL pupae to adult with this mass rearing technique was determined by counting the number of empty mines from 3 plants. Adult flies were collected and counted daily.

Control of Contaminant Species.—Rearing ABL by all techniques was complicated by the presence of several arthropod pests of alfalfa. These damaged the potted plants and contaminated the ABL cultures.

Pea aphid, *Acyrthosiphon pisum* (Harris), was controlled by releasing the braconid *Aphidius ervi* Haliday[4] in the greenhouse. A culture of the parasite was maintained for this purpose. Earlier, occasional outbreaks of

pea aphid were controlled by pirimicarb (2-(dimethylamino)-5,6-dimethyl-4-pyrimidinyl dimethylcarbamate), 50% WP, applied at 0.0025% AI. This material was also used effectively against spotted alfalfa aphid, *Therioaphis maculata* (Buckton), at the same concentration. Pirimicarb caused no mortality to ABL adults or larvae.

Greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), was controlled by sprays of resmethrin ((5-benzyl-3-furyl) methyl *cis-trans*-(±)-2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate), 2% EC, applied at a rate of 0.03% AI. Alfalfa thus treated was toxic to ABL for a few days, so it was not used as host material for at least 7 days after treatment.

Organophosphate-resistant two-spotted spider mites, *Tetranychus urticae* Koch, were controlled in the greenhouse on trimmed alfalfa plants with cyhexatin (tricyclohexylhydroxystannane), 50% WP, applied at a rate of 0.0025% AI. Mites infesting fully-grown plants in the greenhouse that were ready for use or plants already in use in ABL cultures were less effectively, but adequately, controlled by Shell SD-14114 (Vendex®; hexakis (2-methyl-2-phenylpropyl) distannoxane), 50% WP, applied at a rate of 0.0025% AI. SD-14114 at this concentration caused no mortality to ABL adults or larvae or to leafminer parasites of the genera *Opius*, *Phanomeris*, *Diglyphus*, *Closterocerus*, or *Chrysocharis* which were maintained in culture on several agromyzid host species.

Results and Discussion

The most critical period in the rearing of ABL was the pupal stage, the period when mortality was uniformly high. The three techniques of rearing were ca. equally successful during this period: simple technique = 57.1% survival (n = 186), puparia recovery technique = 61.8% (n = 105), and mass rearing technique = 50.6% (n = 211).

The simple technique produced small numbers of flies with minimum maintenance time so it was convenient for rearing ABL for some biological studies or for preliminary work with parasites. The chief difficulty was that production of more than a few flies required considerable laboratory space because the pots had to be left in culture for 40 days until most adults emerged. Another difficulty was that alfalfa plants maintained under artificial lights grew more slowly and had smaller leaflets with longer internodes than alfalfa maintained in greenhouses, thus significantly reducing the leaf area of the plants. However, the simple technique could be even further simplified by eliminating the oviposition cage and keeping adult flies in cages with potted alfalfa permanently.

The puparia recovery method was particularly useful when experiments directly involved puparia, for example studying diapause, or when larval-pupal parasites were to be studied. The advantages included the

direct recovery of puparia and the rapid return of trimmed alfalfa to the greenhouse. The chief difficulty was the greater maintenance time required, more than either of the other 2 methods. This method can also be used to collect large numbers of puparia from infested field alfalfa and should be useful in collecting puparia of other agromyzid species that drop from the host plant to pupate. However, larger agromyzids such as the corn blotch leafminer, *Agromyza parvicornis* Loew, might require screen with a wider mesh than the window screen we used.

The mass rearing technique produced large numbers of flies and so was most useful when host material was needed. It required little maintenance time, made maximum use of laboratory space, and permitted rapid return of trimmed alfalfa to the greenhouse. The only difficulty was that puparia were not directly recovered, but this recovery is necessary for only a few special purposes.

Literature Cited

Miller, D. E., and G. L. Jensen. 1970. Agromyzid alfalfa leaf miners and their parasites in Massachusetts. J. Econ. Entomol. 63:1337–1338.

Footnotes

[1] Diptera: Agromyzidae.

[2] Identified by G. C. Steyskal, Systematic Entomology Laboratory, Agric. Res. Serv., USDA, c/o U.S. National Museum, Washington, DC 20560.

[3] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended. Also, mention of a proprietary product does not constitute an endorsement by the USDA.

[4] Braconid identified by P. M. Marsh, Systematic Entomology Laboratory, Agric. Res. Serv., USDA, c/o U.S. National Museum, Washington, DC 20560.

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THE 49th ANNUAL MEETING

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BOSTON, MA

Abstracts of papers presented at sessions, workshops, and symposia on September 14, 15 and 16, 1977.

The Ecology of the Aphid Predator, *Aphidoletes aphidimyza* (Cecidomyiidae: Diptera), and the Effect of Pesticides on its Survival in Apple Orchards. —R. G. Adams and R. J. Prokopy, Univ. Massachusetts, Amherst, MA 01003.

Larvae of *Aphidoletes aphidimyza* are bright orange colored maggots that feed on many species of aphids. From 1974 through 1976, this cecidomyiid was by far the most abundant summer predator of the apple aphid, *Aphis pomi* DeGeer (Aphidae: Homoptera) in an unsprayed Massachusetts apple orchard. It was responsible for high apple aphid mortality and dramatic population reductions. Apple terminals were caged with various *Aphidoletes* to apple aphid density ratios to study feeding behavior of the larvae. In every case, aphid colonies caged with cecidomyiids were either reduced or decimated within 12 days. The mean number of aphids killed per cecidomyiid was 28, ranging from 4 to 65 depending on predator and prey abundance. Emergence cage studies showed that *Aphidoletes* overwinters in the soil beneath apple trees, but eclosion does not occur until mid-June. Therefore, for season-long control, apple aphid populations need to be maintained below injurious levels until *Aphidoletes* arrives in June. To determine the susceptibility of *Aphidoletes* to orchard sprays, toxicity studies were conducted on eggs using the slide dip method. Egg mortality was generally low with the exception of the Guthion treatment, where mortality was high. However, a few materials that were of low toxicity to eggs were highly (Systox) or moderately (Thiodan and Imidan) toxic to young larvae hatching from treated eggs. Total mortality for eggs and larvae combined was high for Guthion and Systox, moderate for Thiodan and Imidan, and low for Plictran, Omite, and Zolone.

Transmission of Pierce's Disease of Grape by Sharpshooters (Homoptera: Cicadellidae) in Florida.—W. C. Adlerz and D. L. Hopkins, Univ. Florida, IFAS, ARC, Leesburg, FL 32748.

Five species of sharpshooters transmitted the Pierce's disease pathogen from diseased to healthy grape in controlled tests. Three of the species breed on grapes, 2 large sharpshooters that feed on woody tissue, and a smaller one that feeds on leaves. The 2 large sharpshooters *Homalodisca coagulata* and *Oncometopia nigricans* were randomly collected in the ARC Leesburg vineyard from September 1975 through August 1976 and were caged, in 10-insect lots where possible, on indicator plants to test their natural infectivity. Test quantities of *H. coagulata* were not available from November through April and *O. nigricans* was absent from October through February. All 12 lots of *H. coagulata* collected May–October were noninfective. Of 22 lots of *O. nigricans* collected in the vineyard March–Sep-

tember, 3 consecutive lots collected the last 2 weeks in April and the first week in May were infective. Population counts of *O. nigricans* and *H. coagulata* were made weekly on 100 feet of vineyard row in 10 randomly selected segments. Population levels of *Graphocephala versuta*, the leaf feeder, were monitored weekly with 13 × 25 cm sticky boards hung from the trellis wires at various locations in the vineyard. *O. nigricans* sharpshooters migrated to the vineyard in large numbers in the spring and their numbers declined during summer. They were the only sharpshooters on grape in large numbers at the time of Pierce's disease natural spread in 1976. *H. coagulata* populations were initiated in late May and peaked in July, while *G. versuta* populations were initiated in May and peaked in September.

Observations on the Blotch Leafminer, *Agromyza frontella* (Rondani) (Diptera: Agromyzidae) in Massachusetts Alfalfa.—J. T. Andaloro and T. M. Peters, Univ. Massachusetts, Amherst, MA 01003.

The alfalfa blotch leafminer and its damaging effects on alfalfa were first detected in western MA in 1968. Since then *Agromyza frontella* has been reported over most of the northeastern U.S. and also in Quebec and in Nova Scotia. In MA, overwintering adults emerge about 15 May, completing 3 generations throughout the season. Adult females puncture new alfalfa leaflets with their ovipositor (pinholing) and imbibe exuded sap. Up to 75% of the leaflets observed had greater than 5 pinholes and 100/leaflet is common. Heavily punctured leaflets are prone to infection by pathogens and may abscis before harvest. The female also makes egg laying punctures through the lower epidermis of new leaflets where she slips an oval white egg into the spongy mesophyll. In Franklin County, peak egg densities of 29 eggs/54 cm high stem were estimated during the 2nd generation. Upon hatching, the 1st instar mines its way to the palisade layer, readily visible through the upper epidermis. By the 3rd (last) instar, the mine has progressed from a linear stage to an increasingly large blotch. Data taken on a heavily infested field (32 mines/60 cm high stem) in Franklin County during August 1976 indicated that less than 7% of the mines covered more than ⅓ of the leaflet. The majority of these leaves turn brown, dry, and abscis after the larvae have exited to pupate in the soil. Indigenous parasitoids appear to be ineffective in suppressing leafminer populations.

Taxonomy and Phylogeny of the Kermesidae, or Gall-like Scale Insects in the Nearctic Region Based on First Instars (Homoptera: Coccoidea).—R. G. Baer and M. Kosztarab, VPI and SU, Blacksburg, VA 24061.

The genera *Kermes* and *Olliffiella* are included in the Kermesidae which are principally found on oak. Thirty *Kermes* species have been previously described, based primarily on external characteristics of the adult females. The descriptions overlap considerably and no suitable keys have been prepared. These old females are considered worthless and cannot be slide-mounted because of their hard, sclerotized external character. First instars entrapped under or in the females, on the buds and twigs and in bark crevices were studied microscopically to estimate the number of species which actually exist. *Olliffiella* is considered primitive morphologically. Branching from a common stem with the *Olliffiella*, *Kermes* has divided into 3 main groups based on morphology. These groups subdivide into a total of 10 morphologically distinct species or species groups. Of these 10, 2 are new. The known habitat of *Olliffiella* and 1 main *Kermes* group is considered primitive because of its association with the leaves. The other 2 main groups of *Kermes* are found on different parts of the tree, indicating an evolution toward a more protected habitat. Studies based on correlations between morphology and habitat have resulted in the probable phylogenetic interpretation of *Kermes* and *Olliffiella*.

Evaluation of Bluegrasses for Tolerances to *Blissus leucopterus hirtus* (Hemiptera: Lygaeidae).—P. B. Baker, Univ. Maryland, College Park, MD 20742 and R. H. Ratcliffe, USDA, Beltsville, MD 20705.

Cultivars of Kentucky bluegrass (*Poa pratensis* L.) were evaluated in the laboratory for tolerance to the chinch bug (*Blissus leucopterus hirtus* Montandon). Chinch bugs were reared on corn stem sections in ½-pint cardboard containers. Corn was cut into 7.5-cm sections and coated with paraffin at one end, after which sections were surface sterilized in 2% chlorox solution and placed in containers with 1st instar nymphs. Sections were changed weekly. Development time from egg eclosion to adult was 4–6 weeks. Grass cultivars were evaluated for tolerance to adult feeding when approximately 1 month old. Selections were seeded in 15.2-cm pots in 4 tufts (groups) of seed/pot. Tufts were thinned to 5 plants 7–10 days prior to infestation and cut to 3.8 cm the day of infestation. During infestation plants were confined within a plastic cylindrical cage 10 × 20.3 cm high. The cage was divided longitudinally by a flat piece of clear plastic glued between the halves of the cylinder. Adults were placed in one side of the cage; the other side served as an uninfested check.

Following infestation, regrowth, yield, percent dry matter, root development, plant survival and tillering were recorded. At infestation rates of 2 adults/plant or higher, plants were severely injured and top and root growth significantly reduced. There were also significant differences in regrowth, yield, percent dry matter and plant survival among cultivars, indicating that these may be useful criteria for measuring tolerance.

Virulence of *Autographa* baculovirus (NPV) to *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae): Effects of Purification Method and Bioassay Food Source.—D. G. Baugher, W. G. Yendol, and R. Thomas, The Pennsylvania State Univ., University Park, PA 16802.

Polyhedral inclusion bodies (PIBs) of *Autographa californica* nuclear polyhedrosis virus (AcNPV) were propagated in *Trichoplusia ni* larvae and purified by 3 methods. Field stock AcNPV was prepared by maceration, differential centrifugation and pelleting through 40% sucrose. Dried field stock AcNPV was prepared by trituration, differential centrifugation, pelleting through 40% sucrose, and air-drying the final pellets. Laboratory stock AcNPV was prepared by trituration, differential centrifugation, sequential pelleting from 4 M urea, dH_2O, 1.0% sodium dodecyl sulfate, 0.5 M NaCl, and banding in 40–65% sucrose gradients. Feeding phase 8-day posteclosion 4th instar larvae were individually fed doses of AcNPV on 0.25 cm^2 cabbage disks and/or 100 mm^3 diet plugs. Larvae were then reared individually on diet until death or pupation. Probit-mortality log-dosage lines were determined for each preparation. AcNPV purified by different methods and bioassayed on different food sources showed a wide range of activity, with LD_{50}s of 10–345 PIBs/larva. Laboratory stock AcNPV was more virulent than field stocks on the same food sources when LD_{50}s were compared. Virus ingested on diet plugs was more virulent than virus ingested on cabbage disks. Although $r^2 > 93\%$ for all regressions, laboratory stock AcNPV showed least variability. Dried field stock virus was least virulent when compared to other stocks that were administered to diet plugs.

EL-494 A New Molt-inhibiting Insecticide.—D. F. Berard, J. L. Miesel, B. A. Scott, Lilly Research Laboratories, Eli Lilly & Company, Greenfield, IN 46140.

EL-494, *N*-[[[5-(4-bromophenyl)-6-methyl-2-pyrazinyl]-amino]carbonyl]-2,6-dichlorobenzamide, is a new molt-inhibiting insecticide. Acting as a stomach poison, it is effective in controlling a variety of insect pests. Laboratory studies with EL-494 have demonstrated 100% control of southern

armyworm *Spodoptera eridania* larvae at 1–5 ppm, Egyptian cotton leafworm *Spodoptera littoralis* larvae at 10 ppm, and greater wax moth *Galleria mellonella* larvae at 50 ppm, diet incorporated. Diptera controlled by EL-494 include yellow-fever mosquito *Aedes aegypti* at 0.1 ppm, water incorporated, and housefly *Musca domestica* at 50 ppm, diet incorporated. While providing only 75% control of Mexican bean beetle *Epilachna varivestis* at the 2nd to 3rd larval instar molt at 1,000 ppm, EL-494 provides 100% control during the larval to pupal molt at 25 ppm. The increased sensitivity of last stage larvae to EL-494 has also been demonstrated with southern armyworm. Complete reproductive suppression has been observed after Mexican bean beetle and housefly adults were fed EL-494. Treated adults produce eggs that fail to undergo proper egg eclosion. Field tests have also demonstrated that EL-494 has provided good-to-excellent control at 0.28 kg/ha of imported cabbageworm *Pieris rapae* and cabbage looper *Trichoplusia ni* on broccoli and cabbage, velvet-bean caterpillar *Anticarsia gemmatalis* on soybean and fall armyworm *Spodoptera frugiperda* on sweet corn.

Components of the Aggregating Pheromones of *Pissodes* (Coleoptera: Curculionidae) Weevils.—D. C. Booth, A. Claesson, G. N. Lanier and R. M. Silverstein, SUNY Coll. Environ. Sci. and Forestry, Syracuse, NY 13210.

Field studies conducted in central New York tested the attractiveness of 2 compounds isolated from *Pissodes strobi* (Peck). Previous tests showed that *P. strobi*, the white pine weevil and *P. approximatus* Hopkins, the northern pine weevil, were cross-attractive to male-produced aggregating pheromones released from breeding sites appropriate for the respective species. The monoterpene alcohol, grandisol, and corresponding aldehyde were isolated by extraction of volatiles from live *P. strobi* and their crushed abdomina. In late summer of 1976, 30 sticky traps utilizing 6 different treatments captured 119 *Pissodes*. Low levels of grandisol and the aldehyde, released from separate plastic vials, were competitive to live male *P. approximatus* when both treatments contained red pine bolts. Attractiveness of grandisol and the aldehyde with red pine was significantly greater than these compounds without red pine. More intensive tests in 1977 captured 422 *Pissodes*, 340 of which were females. Results indicate that the concentration of the chemicals significantly influences the attractiveness, with a higher level of the compounds capturing nearly twice the number of the lower level. Neither the alcohol nor the aldehyde was highly attractive individually. We conclude that the 2 male-produced compounds and host volatiles act synergistically to attract both sexes of *P. approximatus*.

Effect of Molting Disruptants on *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae) Viability and Reproduction.—J. Brushwein and J. Granett, Univ. Maine, Orono, ME 04473.

Two insect growth regulators (IGRs) which disrupt molting, 50% WP EL-494 and 25% WP Dimilin® were tested in the laboratory against eastern spruce budworms. Field collected, newly molted, 6th instars were fed solely balsam fir foliage previously dipped in toxicant solutions of 400 ppm, 40 ppm, or 4 ppm, or 400 ppm carrier solution alone, and air-dried. Ten replicates of 10 insects each were used for each chemical and rate, and sufficient larvae were reared on untreated foliage for matings. Complete mortality occurred at the 400 and 40 ppm toxicant levels prior to adult emergence. The pupal LD_{50} for Dimilin was close to 4 ppm. The pupal LD_{50} was above 4 ppm for EL-494. However, EL-494 also caused high mortality in emerged adults. Matings between adults reared through on EL-494 and untreated individuals produced no viable eggs. Dimilin did not reduce reproduction of treated males mated with untreated females but did reduce reproduction of treated females mated with untreated males. Neither set of carrier-treated insects had reduced viability or reproduction. Both IGRs caused formation of morphological abnormalities in pupae similar to juvenile hormone analogue affected individuals. Abnormalities included presence on the pupae of larval prolegs, larval thoracic legs, larval head capsule, and malformed wing pads. In many individuals EL-494 caused adults to emerge incompletely from the pupal skin. These materials may have potential for spruce budworm control when applied during the 6th instar.

Morphology and Taxonomy of Gall-like Scale Insects *Kermes* spp. (Homoptera: Kermesidae) in Eastern North America.—S. W. Bullington and M. Kosztarab, VPI and SU, Blacksburg, VA 24061.

Female scale insects of the genus *Kermes*, parasites of trees of the genus *Quercus*, are virtually unidentifiable to species. Most of the descriptions of the 10 eastern species are based on postreproductive females, whose body shape and color pattern are subject to great changes. They are also difficult to mount on slides. Keys have never been prepared. A revision of the group in North America has revealed that postreproductive females have highly vaulted venters separated from the substrate by anteriorly- and posteriorly projecting flaps. These flaps, or "pseudoventer," are species specific in shape, as is the architecture of the cavity enclosed by the true venter. Seven of the species appear to be synonyms; the remainder can be divided into 3 groups based on the pseudoventer: those with 2 anterior

and 2 posterior flaps (*K. pubescens*), those with a single, median anterior flap and 2 posterior flaps (*K. andrei* and one undescribed species), and those with a median, posterior flap as well as 2 anterior and 2 posterior lateral flaps (*K. galliformis* and one undescribed species). Within each group the species differ in the shape of the flaps, as well as in the extent the cavity they enclose is hollowed. Other distinctive characters are visible only on prereproductive adult females that have been slide-mounted. This correlation between slide-mounted, prereproductive and dry-preserved, postreproductive material will make it possible to swiftly and accurately identify the latter, the most commonly noticed stage.

Alternate Methods of Cockroach Control: Other Approaches.—G. S. Burden, Insects Affecting Man Research Laboratory, ARS, USDA, Gainesville, FL 32604.

Present and potential alternatives for the reduction of cockroach infestations are usually less spectacular and sometimes less efficient than the methods of residual sprays, dusts, and aerosols that are the essential mainstays in control programs. However, some of the alternate methods have usefulness as sole approaches or in integrated control programs directed against assorted species of cockroaches, whereas other alternate methods are very limited or impractical in their usefulness. Insecticidal baits may be considered an alternate method of cockroach control because they are the least used of the chemical approaches. Baits offer the possibility of efficient insect control where other methods cannot be used, or in environments where they can be included with insecticidal sprays and/or dusts. Chemosterilants have been evaluated in the past and have been shown to function as sterilants to male and female cockroaches. However, the practical usefulness of chemosterilants is precluded by the long life cycle of the pestiferous cockroaches. Chemicals that function as repellents to cockroaches could be useful alone or in integrated control programs to prevent the aggregation, reinfestation, and transportation of cockroaches. Many factors inherent in the activity of parasites, pathogens, predators, pheromones, and hormones render these as potential but limited approaches for the control of the species of cockroaches that are of major importance in human environments. Exclusion and sanitation are preventive methods that should be the basic approaches to all principal and alternate methods used in control programs.

Cytology of Urate Storage in *Periplaneta americana* (L.) (Dictyoptera: Blattidae).—D. G. Cochran, VPI and SU, Blacksburg, VA 24061.

Urate storage in the American cockroach has been well documented, and shown to occur primarily in the fat body. The level of urate storage is known to be influenced by the amount of nitrogenous material contained in the diet. Cytologically, the fat body consists of 3 types of cells: trophocytes, mycetocytes, and urate cells. Presumably, urates are stored only in urate cells, but the cytological implications of varying levels of urate storage, imposed dietarily, have not been investigated. In order to do so, tissue squashes, cryostat and epon sections of fat body from adult males have been studied with either the light or the transmission electron microscope. Dietary regimes consisted of dextrin, dog food, 24%, 42% and 66% casein protein. The results confirmed the presence of 3 cell types in fat body. Normally, urate cells lie near mycetocytes and neither are found close to the periphery of a fat body lobe. On a dextrin diet essentially no urates are present, but collapsed urate cells are detectable. As dietary nitrogen increases, urates can easily be detected because of their birefringence under polarized light. Urate cells become increasingly packed with urate crystals, and both urate cells and mycetocytes increase in numbers. At the higher dietary nitrogen levels, fat body is often overwhelmed with urate deposits. These findings provide a firm cytological basis for understanding how urate storage is accomplished in this insect.

Resistance and Cross-resistance in Cockroaches (Orthoptera).—W. J. Collins, Ohio State Univ., Columbus, OH 43210.

Data on insecticide resistance in German cockroaches, *Blattella germanica*, are summarized from published reports. Although there are exceptions, the following generalities have emerged from resistance studies in this species: 1) DDT-resistant cockroaches are not resistant to insecticides in other major groups; 2) chlorinated cyclodiene and/or lindane resistance does not involve resistance to other groups; 3) diazinon resistance confers resistance to other organophosphates, including malathion, and may cause resistance to pyrethrins, DDT and propoxur; 4) malathion resistance may not involve resistance to other organophosphates; 5) propoxur resistance confers resistance to other carbamates and may include resistance to organophosphates, including malathion, pyrethrins and DDT. Resistance ratios will vary significantly, depending upon the method that is employed. The most common techniques are: topical application, dipping, direct spray and tarsal contact on glass, wood, masonite or paper. Knockdown and mortality are the most common response criteria. Male cockroaches are

generally less resistant than females. The inheritance of resistance has been studied most extensively in laboratory colonies. Resistance is generally a monofactorial trait that is not sex-linked. Resistance may be recessive (diazinon, propoxur), semidominant (aldrin, DDT, pyrethrins) or dominant (malathion). Chlordane resistance is apparently a fairly stable phenotype; reversion to susceptibility is slow when insecticide pressure is discontinued.

Mortality of *Parasetigena silvestris* and *Blepharipa pretensis* (Diptera: Tachinidae) under Controlled Overwintering Conditions.—D. S. Dalton, Univ. Virginia, Charlottesville, VA 22903.

Overwintering mortality of 2 tachinid parasites of *Lymantria dispar*, *P. silvestris* and *B. pretensis*, was investigated under 5 artificial conditions as a part of a parasite establishment project. Two treatment groups were overwintered outdoors in Morristown, NJ where the insects were collected. In the first, parasites were put in soil-filled trays as maggots free to seek their depth and position with a minimum of handling and storage. The second was a tray filled with alternating layers of sifted soil and fly puparia. The majority of puparia were transported to Charlottesville, VA to be placed in 1 of 3 treatments. The first treatment was a layering of puparia and soil medium in a tray which was buried in woods surrounding the lab. The second involved the same layering but overwintered in a controlled temperature and humidity chamber. In the third treatment, also placed in the environmental chamber, the puparia were surface sterilized and placed in autoclaved soil. Samples of insects overwintering in Virginia were dissected in August and December to determine distribution of mortality during the overwintering period. Results of the study showed: 1) mortality was significantly lower in the NJ treatments which involved a minimum of handling and storage, 2) no differences in mortality between any of the 3 VA treatments in which survival was uniformly low, 3) mortality peaked following pupariation and preceding emergence, 4) parasites that began the experiment as maggots had significantly lower mortality than those that began as pupae and 5) sterilization of puparia and soil had no effect on survival.

Status of the Red Pine Scale, *Matsucoccus resinosae* B. & G. (Homoptera: Margarodidae).—E. J. Duda, Univ. Connecticut, Storrs, CT 06268.

In the 31 years since it was first recorded, the red pine scale has become one of the most serious pests of red pine. It also attacks Japanese black, Japanese red, and Chinese pines. The scale is a killer that shows no preference for tree size. Although the areas of known infestation are restricted

to Connecticut, New York and New Jersey; the scale is a serious threat to planted and natural stands of red pine in the northeast and Lake States. Extensive studies have been conducted on control, but there is as yet no effective, practical means of achieving this end. Two generations of *M. resinosae* occur in a growing season, crawlers of the first appearing in June, those of the wintering brood in August and September. Mortality within a single generation normally is very high. It is determined by physical factors, predators and intraspecific competition. Highest mortality occurs in the neonate crawler stage. Low temperatures could play a role in restricting northward spread. Biological control factors appear to be limited to the work of predators of which an anthocorid bug, *Xenotracheliella inimica* D. & H. is the most effective. Life tables demonstrate the existence of 3 periods when the scale population is drastically reduced. These are the period from egg to sessile form of 1st-stage larva of summer and winter generations, and during the sessile form of over-wintering generation.

The Control of Apple Insect Pests in New Hampshire 1974–1977.—G. T. Fisher, Univ. New Hampshire, Durham, NH 03824.

During the 3-season period 1974–1976, replicated and randomized efficacy trials were conducted in a mature, experimental 10-acre apple orchard in Durham, NH. Varieties within the orchard were standard Red Delicious, McIntosh and Cortland. Materials were applied as a (1×) spray averaging 300 gal/acre at 300 psi to the run-off of both leaves and fruit. Treatments were replicated 3–4 times and randomized as single tree replications. Applications were made at ½ inch green, pink, bloom (fungicide only), petal fall, and 6 cover applications. Fruit (100/replicate) at harvest were examined for damage from the following insects: the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois); the red-banded leafroller, *Argyrotaenia velutinana* (Walker); the codling moth, *Laspeyresia pomonella* L.; the plum curculio, *Conotrachelus nenuphar* (Herbst); the apple maggot, *Rhagoletis pomonella* (Walsh). Materials used in these experiments were: Furadan (carbofuran); ICI PP556 (NRDC 104); Phosvil (leptophos); Carzol (formetanate); Dimilin (TH-6040); Lannate (methomyl): CGA 18809; Mobil 9087; Zolone (phosolone); Imidan (prolate); Guthion (azinphos-methyl). Recommended experimental rates were suggested by the manufacturer. Zolone, Furadan ICI PP557 (4 fl. oz.), Phosvil, Carzol and Lannate give excellent control of plum curculio, apple maggot, codling moth and red-banded leafroller, however, only Mobil 9087 gave economic control of the tarnished plant bug. Fair control of the plum curculio shown by Imidan and Guthion was due to an irregular season (1976) with abnormally high population in plots (check showed 257.3 stings/100 fruit).

The Control of Adult Black Flies (Diptera: Simuliidae) with ULV Ground Apparatus in New Hampshire.—G. T. Fisher and J. W. Martin, New Hampshire Exp. Sta., Durham, NH 03824.

Over a 3-year period, 7 insecticides were tested for efficacy on adult black flies, *Simulium venustum* Say, *S. tuberosum* Lundstrom, and the *Prosimulium mixtum* Peterson complex, in the White Mountains of New Hampshire. The control of these insects is especially vital to tourist trade, and the use of adulticides provides limited control for short periods of time. Malathion 57% EL, Dibrom 8 and 14, Baygon 70% WP and 1 MOS, Sumithion ULV and Pydrin 8 EC were applied at the manufacturer's recommended rates in the towns of Waterville Valley and Dixville Notch, NH. Plots consisted of open, wooded and residential areas. Adult black fly populations were sampled before treatment and at 30 min, 1, 4, 8, 24, 48 and 72 h after treatment. Malathion 57% EL, unlike the other formulations, showed no efficacy. The ultra low volume formulations, when applied through a BEECO-mist nozzle fitted on a John Bean Mist Blower, showed both efficacy and ease of application. Dibrom 14 gave 100% control within 4 h, but showed no appreciable residual quality; Baygon 1 MOS showed better residual quality with lesser knockdown; Sumithion ULV gave excellent control and Pydrin 8 EC, tested only in 1977, showed potential efficacy. This method of control is suitable in small areas where aerial pesticide application is restricted.

Chemical and Physical Factors Affecting the Feeding of Female *Culiseta inornata* (Williston) (Diptera: Culicidae).—W. G. Friend, Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

The feeding responses of mosquitoes are complex. Both males and females drink water and feed on nectar, females also feed on blood. Blood usually goes to the mid-gut, sugar solutions to the crop. It is generally believed that the destination of the meal is directed by chemicals in the diet and is independent of the mode of feeding. Recent work with *C. inornata* in our laboratory has shown that the mode of feeding can significantly affect the responses to ATP, the phagostimulant found in blood that induces most haematophagous insects to gorge. If females are presented the artificial diet containing ATP as a free liquid at room temperature, they accept it as they would water, taking between 0.01 and 1.33 μl and directing it to the mid-gut. If the same diet is presented under a silverlight membrane at blood temperature the females take 1.02 to 3.68 μl into the mid-gut. By manipulating the relative amounts of ATP and sucrose in the artificial diet changes in the threshold of response to these phagostimulants can be demonstrated as the mode of feeding is changed.

Compsilura concinnata (Meigen) (Diptera: Tachinidae): Longevity, Development, and Production of Progeny on the Gypsy Moth.—R. A. Fusco, Pennsylvania Dept. Environ. Resources, Middletown, PA 17057.

The effect of several constant temperatures on the ability of *C. concinnata* to increase in numbers was studied in the laboratory for maximizing production in a mass-rearing program. Successful development from 1st-stage larva to adult occurred within a temperature range of 15.6–29.4°C. At 32.2°C, the highest temperature tested, adult flies failed to emerge. Percent parasitism and adult emergence were greatest between 15.6 and 23.9°C. Mean number of puparia/host was highest in larvae exposed between 18.3 and 26.7°C. Both larval and pupal development time varied inversely with temperature within the range of 15.6–26.7°C. Longevity and duration of both prelarviposition and larviposition were inversely related to temperature. Production of puparia by individual females was highly variable. Males were capable of multiple mating, and effectively fertilized as many as 6♀. The results of these tests indicate that an ideal rearing program would incorporate the following environmental regime, tailored for optimum yield of specific parasite life stages: 1) 21.1°C for high adult activity periods (mating and parasitizing); 2) 26.7°C for larva and pupa developmental periods (pre- and postlarviposition and preemergence adult development); and 15.6°C for storage of adult flies overnight or between periods of host exposure and larviposition. Parasite progeny may be stockpiled in the pupal stage for 2–4 weeks at 10–15.6°C, or as developing maggots in host larvae at 10–15.6°C for up to 2 weeks.

Trail Following Behavior in the Gypsy Moth Caterpillar *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae).—E. M. Gallagher and G. N. Lanier, SUNY, Syracuse, NY 13210.

Gypsy moth larvae were observed in a light infestation on red and white oaks in Clay, NY, to examine the role of silk trails in larval movements. On an area of a tree that was observed to have silk on it, two 8 × 16.5 cm sections were marked off. The silk was removed from one section by brushing vigorously with a stiff, plastic-bristled brush, while the other section served as a control. The response of larvae to the treatment area was generally a marked hesistancy or refusal to cross, while larvae readily crossed the control area in all trials. To examine the involvement of trail following chemicals in gypsy moth silk, 2 additional areas were marked off. Hexanes were used to extract the silk in one area by dripping it down the tree trunk from the top and collecting it at the lower border of the section. The second area was a control. Larval response to the extracted area was similar to

responses to a desilked area. Most hesitate or refuse to cross the treatment section, while few respond in that manner to the control. These results indicate that gypsy moth larvae may be using a trail system to relocate established resting and/or feeding sites, and that the nature of these trails may be chemical, similar to those reported for other Lepidoptera larvae. They further form the basis for continuing investigations into the nature and chemistry of a gypsy moth trail system.

Musca autumnalis (DeGeer) (Diptera: Muscidae) as vector of *Thelazia* sp. (Bosc) (Nematoda: Filaroidea) in Massachusetts.—C. J. Geden and J. G. Stoffolano, Univ. Massachusetts, Amherst, MA 01003.

The genus *Thelazia* includes several species of parasitic eyeworms of cattle and horses. *T. gulosa* and *T. skrjabini* have been recovered from the eyes of cattle in Kentucky and Massachusetts while *T. lacrymalis* has been found in horses in Maryland, Kentucky and Ontario. Adult worms generally live in lachrimal ducts of mammals where they deposit 1st-stage larvae into the eye secretions ingested by feeding face flies. The worms penetrate the gut and become surrounded by a capsule in the abdomen of the fly where they develop into invasive-stage larvae. The larvae rupture the capsules, migrate to the head and exit through the proboscis into the eye of a new host. To determine the incidence of parasitism in the flies eighteen collections of female face flies were made from cattle throughout Massachusetts and inspected for *Thelazia* larvae. An average infection rate of 2.6% was found ranging from 0.5–13.2%. The number of worms/fly ranged from 1–30 with an average of 3.2. Of 361 capsules found in the abdomens, 75% were attached to cuticle, 23% to fat body and 2% to Malphigian tubules. Our findings thus suggest that bovine thelaziasis is fairly widespread throughout Massachusetts.

Tsetse Flies *Glossina morsitans* West. (Diptera: Muscidae): Research with African Sleeping Sickness.—J. B. Gingrich, G. H. Campbell, A. B. Bosworth, R. N. Wilkinson and R. A. Ward, Walter Reed Army Inst. of Res., Washington, DC 20012.

Attempted establishment of a self-sufficient colony of tsetse flies for trypanosomiasis studies has shown guinea pigs to be unsuitable hosts since puparial weights decreased steadily from 27.4 mg for the parental (Bristol) flies to 23.8 mg for the F_2 generation while percent emergence concurrently dropped from 95% (parental) to 65% (F_2). Feeding flies on rabbits has significantly improved these measures of colony vigor. Preliminary obser-

vations on flies infected with cloned stabilates of *Trypanosoma rhodesiense* (isolated from a Kenyan in 1975) suggests that some stabilates that have been syringe-passed 10 or more times will not yield mature fly infections, probably due to the midgut establishment barrier. Some success was obtained by growing insect stages of parasites in a tsetse fly-derived cell line, and both primary cultures and several continuous cell lines are being screened for development of the blood stages of trypanosomes. A clone of trypanosomes obtained from the original isolate produced a chronic infection in C57 mice from which 13 serologically distinct variant clones were obtained.

Chemical Control of Resistant Cockroaches.—J. M. Grayson, VPI and SU, Blacksburg, VA 24061.

Efficacious chemicals for controlling normal and resistant cockroaches are reviewed in 6 categories: 1) Residual applications, oil or water extended, from such standard materials as diazinon, propoxur, chlorpyrifos and malathion; and from promising newer chemicals such as bendiocarb, acephate, fenitrothion and others; 2) Slow release residual treatments such as dichlorvos in resins or plastics, encapsulated SBP-1382, encapsulated diazinon, encapsulated fenitrothion and multilayer tapes containing diazinon, propoxur or chlorpyrifos; 3) Dust applications of diazinon, malathion, sodium fluoride, boric acid powder, silica aerogels and pyrethrum plus sulfoxide; 4) Baits of different composition with such toxic ingredients as dichlorvos, propoxur, boric acid, trichlorfon and chlordecone; 5) Knockdown and/or flushing agents, e.g., pyrethrum (either alone or in combination with synergist), dichlorvos and SBP-1382; 6) Synthetic and botanical extracts effective as repellents, e.g., MGK R-874, MGK R-11 and a number of N,N-disubstituted n-aliphatic amides.

Effect of Artificially Administered Steroids, Blocking Agents, and Social Stress in Chickens on Northern Fowl Mite Population Development (Acarina: Macronyssidae).—R. D. Hall and E. C. Turner, Jr., VPI and SU, Blacksburg, VA 24061.

Corticosterone administered intravenously or orally to white Leghorn roosters was shown to inhibit northern fowl mite population development. In roosters genetically selected for a low plasma corticosterone response to social stress, metyrapone and desoxycorticosterone administration increased mite population development over that on control birds. The dosage of orally administered corticosterone required for maximum inhibition of

mite population development in most inbred Leghorn lines tested was between 20 and 30 ppm. Dosages higher or lower than this range often increased the severity of mite infestation. Roosters subjected to extremes of social interaction displayed differences in mite resistance. High levels of social stress resulted in reduced mite population development, while birds housed alone suffered large mite populations within a short time. Post mortem examination revealed that roosters made mite-resistant by steroid administration or high levels of social stress produced poorer weight gains and testes development than mite-susceptible birds in low-stress environments and on non-steroid feed. Initial tests showed that the mechanism of mite resistance in those cases tested resulted from decreased capillary density in the skin proximate to the birds' vents.

Tabanidae of the East Coast as an Economic Problem.—E. J. Hansens, Rutgers University, New Brunswick, NJ 08903.

Tabanidae are pests of man and animals in many areas of the coastal states but especially near salt marshes. The major species, *Tabanus nigrovittatus* and *Chrysops atlanticus*, move from the marshes to nearby beaches, camp grounds, golf courses, and other recreational areas and onto boats in the bays and estuaries. *Chrysops* congregate in dense vegetation and attack when man or animals move into such places. Both *Tabanus* and *Chrysops* are severe problems to agricultural workers when the flies are numerous. Biology and habits of both salt marsh and upland species are poorly known. The problems are further complicated by the probability that *T. nigrovittatus* is a complex of closely related species. The member of the complex in more northern areas is a much more avid feeder on man. Livestock are readily attacked by Tabanidae with consequent effects of thriftiness, weight gains and milk production. Some species transmit causal agents of disease to domestic animals and wildlife. Controls are inadequate though box or canopy traps and vegetative barriers have been shown useful against *Tabanus* and some insecticides have given reduction but not adequate control of both *Tabanus* and *Chrysops*. Livestock cannot now be protected adequately from attacks of Tabanidae.

Observations on Field Behavior of Plum Curculio Adults, *Conotrachelus nenuphar* (Coleoptera: Curculionidae).—K. I. Hauschild, E. D. Owens and R. J. Prokopy, Univ. Massachusetts, Amherst, MA 01003.

The plum curculio is one of the 5 major pests of apple fruit in New England. Although its general biology has been described by several

authors, the behavior of adults is not well known. Our goal is to attain sufficient understanding of adult behavior so that we can develop an effective device for monitoring adult population levels. Within 3 weeks of petal fall, and from dawn to until ca. 1 h after dusk, we observed 47 h of adult curculio behavior on unsprayed apple trees in Masschusetts. The adults spent the majority of their active time crawling on branches, twigs, leaves, and fruits apparently in search of food or ovipositional sites. However, resting in protected places, such as twig crotches and the calyx end of the fruit, was the most frequently observed behavior. Only 5 of the 70 curculios observed flew. Fruits were located apparently via tactile stimuli, with distribution of oviposition scars among fruits and branches of sampled trees being random rather than uniform. Overall, our findings show that compared with the within-tree activities of apple maggot, European apple sawfly, and tarnished plant bug, plum curculios fly much less frequently and are much less visually oriented. Therefore, sticky-coated visual traps are of dubious potential value for monitoring adult curculio populations. In addition, continuous monitoring with funnel traps on the ground beneath infested trees indicated little dropping of curculios from the canopy during calm weather, though some dropping during windy periods. Funnel traps are therefore also of doubtful value for accurate monitoring.

Evaluation of *Akis bacarozzo* Schrank (Coleoptera: Tenebrionidae) as a Predator of Eggs of the Gypsy Moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae).—R. C. Hedlund, Benefical Insects Research Laboratory, USDA, ARS, Newark, DE 19713 and J. S. Russin, Univ. Delaware, Newark, DE 19711.

Akis bacarozzo was reported by USDA, ARS cooperators in Morocco to be a predator on eggs of the gypsy moth. In June 1975, 148 adults of this beetle were collected and sent to the ARS quarantine laboratory in Newark, DE, for evaluation. Identification of the species was determined by T. J. Spilman of the USDA Systematic Entomology Laboratory. The adult beetles were long-lived, surviving for more than 2 years in the laboratory. Mating was common and up to several hundred eggs were collected weekly. The eggs hatched in 13 days at 21°C. Both larvae and adults fed readily on semi-moist dog food although no larvae were reared to pupation. Both larvae and adults were supplied with gypsy moth eggs as food. The larvae ate only de-haired eggs and only when there was no other food available. The adult beetles fed on gypsy moth eggs only when starved for periods of 11–30 days. In some instances the adults died without feeding. The adults fed readily on rolled oats, white rice, buckwheat, cut oats, rye, corn,

soybeans, hardwheat and soft wheat. Neither the adults nor the larvae of this predator attacked live gypsy moth larvae although the adults were observed to feed slightly on dead gypsy moth larvae. From these tests it was concluded that *Akis bacarozzo* had little or no potential as a predator on gypsy moth eggs.

Mineral requirements for brood rearing by *Apis mellifera* L. (Hymenoptera: Apidae) fed a synthetic diet.—E. W. Herbert, Jr. and H. Shimanuki, USDA, Agricultural Research Service, Beltsville, MD 20705.

The mineral requirements of honeybees have been neglected in nutritional studies. Additional research is essential since Wesson's salts and other salt mixtures designed for vertebrates have proved ineffective in honeybee diets. Since pollen constitutes the predominant source of minerals for honeybees, atomic absorption techniques were used in chemical analyses of pollen ash for the following elements: potassium, sodium, calcium, magnesium, zinc, mangenese, iron and copper. Also, the optimum level of ash for brood rearing was determined by feeding honeybees five levels in a chemically defined diet containing 18 amino acids and 10 water soluble vitamins. In this study, each diet was offered to nuclei containing newly emerged bees and a mated queen held in a screen flight cage. The production of sealed brood and diet consumption were measured weekly. Bees fed a synthetic diet fortified with 1% pollen ash supported the greatest quantity of brood followed, in descending order, by bees fed diets fortified with 0.5, 2.0, 4.0, 0.0 and 8.0% ash. Bees were able to rear brood when fed an ash-free diet, but the addition of pollen ash resulted in improved brood rearing. Bees fed the diets containing the higher ash levels (4.0 and 8.0%) had high initial mortality, and the larval and adult populations began to dwindle early. This suggests that the ash content of pollen (mean 3.17%) may not be optimum for maximum colony development.

Sex Pheromone of the Black Cutworm Moth, *Agrotis ipsilon* (Hufnagel) (Lepidoptera: Noctuidae).—A. S. Hill and W. L. Roelofs, NYS Agr. Expt. Sta., Geneva, NY 14456, and R. W. Rings and S. R. Swier, Ohio Agr. Res. Develop. Center, Wooster, OH 44691.

The black cutworm is a widely distributed agricultural pest for which the availability of a specific attractant could be very useful. We have identified (Z)-7-dodecenyl acetate (I) and (Z)-9-tetradecenyl acetate (II) as components of its sex pheromone. These compounds are emmitted by the female and, in combination, they attract the male moths. They were iden-

tified by their adsorption (liquid) chromatographic and gas chromatographic (GC) properties, mass spectral patterns, and chemical reactions (alkaline hydrolysis and reacetylation; ozonolysis products). Crude and treated female abdominal tip extracts were assayed by 2 methods: electroantennographic and wind tunnel (flight chamber) bioassays. Electroantennograms revealed only the presence of I. In a wind tunnel, both components were required to elicit upwind flight, through the chemical plume and terminating at the chemical source, by the male moths. Some upwind anemotaxis was seen with I alone, but it was not sustained and did not result in arrival of the insect at the chemical source; none was seen with II alone. Various combinations of I and II on rubber septa (1:1 and 3:1, 3 μg to 100 μg of each) or dispensed from capillary tubes sealed at one end (1:1 to 10:1, 1–4 capillary tubes) are effective lures in the field; neither I nor II alone is effective. Small amounts (1% or less) of the corresponding (*E*)-isomers appear to have no effect on trap catches.

Influence of Pesticides on Predacious and Phytophagous Mite Populations in Massachusetts Apple Orchards.—R. G. Hislop, C. Acker, and R. J. Prokopy, Univ. Massachusetts, Amherst, MA 01003.

The population dynamics of several species of phytophagous and predacious mites were determined in 1976 in 5 commercial and 3 abandoned apple orchards. A phytoseiid, *Amblyseius fallacis* (Garman), and a stigmaeid, toseiid, *Zetzellia mali* (Ewing), accounted for the majority of predators in orchards using spray programs with different combinations of Guthion, Imidan, Captan and Cyprex. European red mite, *Panonychus ulmi* (Koch), and apple rust mite, *Aculus schlectendali* (Nal.) were the dominant phytophagous species. Mite predator populations were extremely low in orchards using Zolone, Glyodin, and Benlate in different combinations with the previous materials. Two-spotted mite, *Tetranychus urticae* Koch, appeared in moderate to high numbers whereas rust mite and red mite were relatively low in abundance. More miticide applications were necessary in orchards using the latter materials. In orchards abandoned at least 8 yr two-spotted mite was not found and European red mite was relatively scarce. Phytoseiid mites, particularly *Typhlodromus pomi* (Parrot), and *Phytoseius macropilus* Banks, were found in moderate to high numbers. Laboratory toxicity studies on adult females of pesticides at normal field concentrations (using the slide dip method) indicate Zolone and Glyodin are highly and moderately toxic to *A. fallacis* and of low toxicity to *T. urticae*. Guthion, Imidan, Captan and Cyprex were of low toxicity to both species. This suggests that *A. fallacis* cannot survive where Zolone and Glyodin are used, thereby allowing buildup of two-spotted mite.

Scanning Electron Microscope Studies of Haller's Organ for Systematic Purposes in the Tick Genus *Ixodes* Latreille (Acari: Ixodidae).—P. J. Homsher and D. E. Sonenshine, Old Dominion Univ., Norfolk, VA 23508.

Scanning electron microscopy provides an excellent tool for studying the undistorted form of external surface features in more detail and with more accuracy. In turn, the biosystematist can identify subtle differences in important taxonomic characters that are not possible to analyze by other microscopic means. Ten characters are identified that show distinct differences among the species examined. These are (1) shape of entire organ, (2) shape of anterior trough, (3) height of anterior trough walls, (4) presence or absence of distal transverse wall of anterior trough, (5) location of anterior trough sensilla, (6) shape of posterior capsule aperture, (7) area of posterior capsule aperture, (8) number of tarsal hump setae, (9) location of tarsal hump setae and (10) size of tarsal hump setae. These characters have been applied to Haller's organs of representatives of 15 species of *Ixodes*, some of which are very similar in gross morphology (e.g., *Ixodes brunneus* and *Ixodes frontalis*). Discontinuous variation has been observed between well defined species as well as between those with similar morphology. Use of SEM for systematic purposes must be in conjunction with other analyses of the taxonomic relationships in the genus. However, it appears that the differences identified in Haller's organ by use of the SEM corroborate the relationships proposed using other characteristics and are definable at a level equal to them when used to establish species limits.

Biological Control and Lifestyles of Parasitic Hymenoptera.—D. J. Horn, Ohio State Univ., Columbus, OH 43210.

Does introduction of several parasite species result in more effective biological control than introduction of a single "best" species? I compared reproductive biologies of parasitic Hymenoptera associated with the alfalfa weevil (*Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae)), cereal leaf beetle (*Oulema melanopa* (L.) (Coleoptera: Chrysomelidae)), bagworm (*Thyridopteryx ephemeraeformis* Haworth (Lepidoptera: Psychidae)) and California oakworm (*Phryganidia californica* Packard (Lepidoptera: Dioptidae)). Lifestyles of these parasites tended toward one of 2 extremes: 1) high fecundity, short handling time, larger size, monophagy, rapid dispersal ("r-strategist" or "dumper"), and 2) low fecundity, long handling time, smaller size, polyphagy, slower dispersal ("K-strategist" or "plodder"). These parameters are easily measurable in field and laboratory. Computer simulations based on these observations show that a "dumper" will be established more quickly, and can reduce host numbers from high densities, whereas a

"plodder" is more likely to contain the host at low densities. Effective biological control therefore results from importation of parasitic wasps representing both extremes, i.e. a multispecies complex rather than a single "best" species. Initial consideration should be given to "dumpers" whose attack rates exceed oviposition and/or growth rates of their host.

Beech Bark Disease (*Cryptococcus fagi* Baer. (Homoptera, Coccidae, Ericoccidae) and *Nectria* spp.)—Status in Europe and United States.—D. R. Houston, USDA, Forest Service, Hamden, CT 06514.

Beech bark disease (BBD) results when heavy attacks by *C. fagi* predispose beech trees to *Nectria coccinea* (Europe) and *N. coccinea* var. *faginata* (North America). *C. fagi* and BBD are widespread in Europe with damage currently heavy in young plantations in southern England and older ones in western France; and increasing in plantations of southern Germany. In England, scale buildup on young trees is favored by heavy protective coatings of the bark lichen, *Lecanora conizaeoides*. On some trees, the bark fungus, *Dichaena rugosa*, appears to restrict *C. fagi*. As the scale, introduced to Nova Scotia in 1890, spread through Maine, New Hampshire and Vermont, heavy tree mortality occurred. The complex is causing serious losses in eastern New York and Pennsylvania. In long-affected forests of New England, another scale, *Xylococculus betulae*, causes severe defects that provide spatial niches for *C. fagi*, often on trees too small to be generally susceptible. Evidence suggests that BBD will once again cause serious problems in areas hard hit several decades ago.

INKTO: The National Reference Collection of Insect Pests not Known to Occur in the United States.—P. A. Kessler and L. Knutson, Insect and Beneficial Insect Introduction Institute, USDA, ARS, Beltsville, MD 20705.

A collection of insect pests not known to occur in the United States is maintained and distributed by the Insect Identification and Beneficial Insect Introduction Institute (IIBIII). The collection at present includes 59 foreign pests, most of which have been described in the Cooperative Plant Pest Report, or its predecessor, the Cooperative Economic Insect Report, published by the Animal and Plant Health Inspection Service, USDA. The IIBIII attempts to obtain 100 specimens of each species from cooperators and foreign explorations throughout the world. Specimens are authoritatively determined by research taxonomists of the Systematic Entomology Labratory (SEL), IIBIII, and the Smithsonian Institution before being sent to 63 federal and state locations, including 18 APHIS ports of

entry. The purpose of the collections is to facilitate immediate recognition of a foreign pest in an effort to prevent its establishment in the U.S. Collections placed in ports of entry are a reference for APHIS port identifiers who intercept approximately 7,000 species of exotic insects and mites per year. Those not identifiable by a port inspector are rushed to SEL for identification. An average of 1,500 port interceptions not recognizable by port identifiers are sent to SEL each year for "Urgent" determinations while merchandise or cargo is detained pending official determination. Collections placed with state and federal offices will hopefully aid in the detection of new infestations of pests that may be collected through routine surveys, light traps, etc.

Techniques for Associating Developmental Stages of Ceratopogonidae and Other Diptera.—W. I. Knausenberger and E. C. Turner, Jr., VPI and SU, Blacksburg, VA 24061.

We have emphasized 2 main approaches: 1) Indirect association. The most successful technique involved dividing a sample into equal subsamples, extracting the larvae live (for subsequent rearing) from one subsample, and holding the other for adult emergence in uncomplicated but effective rearing cartons. The substrate could be aerated when necessary. 2) Direct association of larval and pupal exuviae for rearing individual larvae. Its main features include use of: a) small covered culture dishes (35×10 mm and 60×15 mm), b) a substrate of non-nutrient agar, solidified at a slant. Batches of agar were prepared with different degrees of firmness (5–10 g agar/1,000 ml dist. water). Smaller larvae did best on softer agar, c) A selection of live food sources, primarily nematodes (*Panagrellus redivivus*) and small amounts of an infusion containing bacteria, algae, protozoa, rotifers, and microcrustacea. Larvae thus were able to seek their preferred food and moisture level within the given limits. Fungal contamination was very rare. Over 40 species of Ceratopogonidae in 12 genera were successfully reared. Development often was successful in over 50% of the attempts, compared with 15% before this technique. Best success was achieved with third and fourth instar larvae. To date, the longest period from initiation of rearing to successful emergence was 8 months. Representatives of Diptera in 10 other families have been reared from larvae by the agar technique, and 20 families by the recovery cartons. Chironomidae and Tipulidae predominated.

Initial Establishment of *Ceuthorrhynchidius horridus* (Panzer) (Coleoptera: Curculionidae) on Thistles in Virginia.—L. T. Kok and J. T. Trumble, VPI and SU, Blacksburg, VA 24061.

Ceuthorrhynchidius horridus, a thistle rosette weevil, was first imported under quarantine from Italy for host specificity tests in 1970. After intensive testing, it was found to be sufficiently host specific and was officially approved for field release in Virginia in 1974. Between 1974–1976, 9 releases at selected sites spread over 5 counties were made: 4 were on *Carduus nutans* L. (musk thistle) and 5 were on *Carduus acanthoides* L. (plumeless thistle). The first release consisted of 30 adults and 2,000 first instars on musk thistle in Montgomery County in October 1974. The adults were placed among a dense patch of rosettes and the larvae were inoculated into the growth points (punctured by forceps) with a fine camel hairbrush. Seven releases of 100 adults each were made in November 1975. Three were on musk thistle (1 in Montgomery Co. and 2 in Pulaski Co.) and 4 were on plumeless thistle (2 in Giles Co., 1 in Warren Co., 1 in Russell Co.). In June 1976, a subsequent release of 200 adults each was repeated in two of the latter sites and an initial release of 160 adults was made on the fifth plumeless thistle site (Warren Co.). Detection surveys conducted annually in March and April showed initial establishment in all except the last site by the spring of 1977. Larvae were found in the meristematic tissues of plants on all 4 musk thistle sites and 4 of the 5 plumeless thistle sites. This is the first report of establishment of *C. horridus* in the U.S.A.

Status of Scale Insects of Forest Trees—An Overview (Homoptera: Coccoidea).—Michael Kosztarab, VPI and SU, Blacksburg, VA 24061.

Losses caused by scale insects in the United States are estimated at $500 million yearly, but we will have to confirm such estimates with more detailed and accurate records in the future. Many species build up high population densities and reach economically important levels only after the trees are predisposed due to physiological stresses, e.g. drought. Individuals of some tree species manifest variation in resistance to scale insect infestation, e.g. juniper scale. Biologies, host preferences, distribution, economic importance, as well as recognition in the field and when mounted on microscope slides, are given for the following scale insect species from the Eastern United States not discussed by other participants of the workshop "Status of Scale Insects on Forest Trees": *Asterolecanium minus* Lindinger on oaks; *Carulaspis juniperi* (Bouché) on junipers and arborvitae; *Chionaspis heterophyllae* Cooley and

C. pinifoliae (Fitch) on pines; *Kermes galliformis* Riley and *K. pubescens* Bogue on oaks; *Pulvinaria acericola* (Walsh & Riley) and *P. inumerabilis* (Rathvon) on maples and other trees; *Toumeyella liriodendri* (Gmelin) on tulip trees and magnolias. All the above listed species have one generation per year in Eastern United States, except *T. liriodendri* with two generations in the southernmost parts of its range, also two generations in *C. heterophyllae* and *C. pinifoliae*.

Determination of the Toxicities of Pirimor, Carbaryl and Monitor to *Coleomegilla maculata lengi* and *Chrysopa occulata*.—S. H. Lecrone and Z. Smilowitz, The Pennsylvania State Univ., University Park, PA 16802.

Knowledge of the effects of insecticides on predaceous insects is part of the complex of information needed to make an informed choice of insecticides in an integrated pest management program requiring insecticide intervention. The dose-mortality response is a means of evaluating the effects of insecticides on insects. Microsyringes were used to topically apply 1 μl volumes of the toxicants in acetone to lab-reared *Coleomegilla maculata lengi* (Timb.) (Coleoptera: Coccinellidae) adults and *Chrysopa occulata* (Say) (Neuroptera: Chrysopidae) 2nd instar larvae. Mortality was determined 24 and 48 h after treatment. The median lethal dose (LD_{50}) for each insect was determined by probit analysis. Between 330 and 450 insects were used to establish these values. The LD_{50} values (μg/insect), 95% confidence limits and slopes of the dosage-mortality curves of the insecticides applied to *Coleomegilla maculata* were carbaryl, .063, .054–.070, 2.85; Monitor, .055, .048–.061, 3.21; Pirimor, 26.351, 24.017–29.741, 3.63. Insecticide responses to *Chrysopa occulata* were carbaryl, .090, .070–.109, 2.27; Monitor, .022, .019–.026, 2.30; Pirimor, 4.441, 3.203–6.253, 1.02. Pirimor was 49- and 202-fold less toxic than carbaryl and Monitor to *Chrysopa occulata* larvae and 418- and 479-fold less toxic to *Coleomegilla maculata* adults than carbaryl and Monitor. Carbaryl was 4-fold less toxic than Monitor to *Crysopa occulata* larvae, but approximately as toxic as Monitor to *Coleomegilla maculata* adults.

Performance of Newly Available Acaricides Against the European Red Mite, *Panonychus ulmi* (Koch) [Acarina: Tetranychidae].—S. E. Lienk, Entomol. Dept., NYS Agr. Exp. Sta., Geneva, NY 14456.

Extensive field screening programs evaluating currently recommended and candidate acaricides were conducted in 1976–77 on apple. Two types of evaluations, namely preventive and eradicative programs were in-

vestigated. Emphasis was placed on early season or preventive type programs in which treatments were applied in the immediate pre-bloom period and directed against the overwintering eggs or newly hatched forms. The bulk of these treatments were applied with an airblast sprayer to unreplicated acre size plots. Population counts were made weekly by collecting leaves and brushing them with a Henderson-McBurnie machine. Eradicative tests were made in mid-summer against established red mite populations. In these trials records were taken directly in the orchard using binocular microscopes. A minimum of three observers counted all mite stages on independently selected subsamples of leaves. Of the pre-bloom treatments, petroleum oil, Plictran and BAAM in most instances gave seasonal control. A seasonal program in which 1 qt oil + 2 oz Benlate was included in every spray application also gave excellent control. Of 4 registered acaricides screened at low rates in three post-bloom sprays only Vendex gave satisfactory control. Candidates DPX 3792 and PP 199, a new diphenylamine acaricidae of 14 products applied against summer populations exhibited the highest control efficiency.

Foraging Behavior and Colony Drift in *Vespula maculifrons* (Buysson) (Hymenoptera: Vespidae).—W. D. Lord, D. A. Nicolson and R. R. Roth, Univ. Delaware, Newark, DE 19711.

Eastern yellowjacket, *Vespula maculifrons*, is a common subterranean nesting species in the mid-Atlantic states. We studied its foraging behavior over a 2-year period in northern Delaware and Maryland. The wasps were predaceous on a diverse group of immature and adult insects and scavengers on fruits, honeydew, vertebrate carrion, and human foods. Marking studies in a 14-ha woodland demonstrated a maximum foraging distance of 275 m from nesting sites. The scavenging habits and foraging distances observed support *V. maculifrons*' inclusion in the *V. vulgaris* (L.) species group. Tagging experiments suggest at least a 1–2% exchange of foraging workers among nests within overlapping foraging ranges. Colony drift is unreported in Nearctic *Vespula*. Existence of colony drift in *V. maculifrons* suggests several questions for future study; 1. Is colony drift indicative of a poorly developed homing ability in *Vespula*? 2. Is there a functional colony-specific pheromone? 3. Are colonies in isolated woodland areas closely related genetically because of their isolation? 4. Is selection for adaptations to maintain colony integrity weak because of the genetic relatedness of these colonies? 5. Is colony drift related to the food resource base of the habitat?

Survey and Population Assessment of the Spiders (Araneae) in an Abandoned, Unsprayed Apple Orchard in Central Virginia.—J. P. McCaffrey and R. L. Horsburgh, Shenandoah Valley Res. Sta., VPI and SU, Steeles Tavern, VA 24764.

Spiders are conspicuous members of the predator complex in Virginia apple orchards. Before a meaningful assessment of their importance as natural control agents of orchard pests can be made the species and populations that are present throughout the season must be determined. Weekly samples consisting of the spiders jarred from the lower branches of ¼ a tree for 4 trees forming a square were taken in an abandoned, unsprayed orchard in central Virginia during June–November 1976 and March–June 1977. A total of 1,117 spiders representing 11 families were collected and approximately 31 genera and 48 species were identified. The Thomisidae, Salticidae, Theridiidae, Anyphaenidae and Dictynidae composed 34, 27, 15, 7 and 7% respectively for a total of 90% of the total spiders collected. Spring and summer peaks of abundance were observed with a mean of 29 spiders per sample in May and 81 in August. Of the 324 spiders collected in August, 42% were thomisids of which 89% were immatures of *Philodromus* sp. In May 39% of the 114 spiders were salticids of which 50% were adults and subadults of *Metaphidippus* sp. (probably *galathea* (Walck)). This study indicates that although a large number of species may be present in the orchard ecosystem, relatively few will predominate and be influential in reducing or regulating orchard pest populations.

Ecology and Control of *Fiorinia externa* Ferris (Homoptera: Diaspididae) on Eastern Hemlock.—M. S. McClure, Connecticut Agr. Exp. Sta., New Haven, CT 06504.

Fiorinia externa is a destructive pest of *Tsuga canadensis* (L.) Carrière in southwestern Connecticut where it also infests 43 species of exotic cedar, fir, hemlock, pine, spruce, and yew. First instars (crawlers) were dispersed by the wind for more than 100 m and preferentially colonized the youngest needles in the lower crown of hemlocks on which they fell. Various edaphic conditions characteristic of sites where hemlock grows naturally significantly influenced survival and development of colonists. Paratitism of second and third instar females by *Aspidiotiphagus citrinus* Craw. (Hymenoptera: Eulophidae) frequently was 50% but in some areas reached 96%. Parasitism was density-dependent within and among hemlock crowns and increased with scale density for three generations. Thorough coverage of foliage with dimethoate insecticide provided excellent scale control (99% mortality). However, partial coverage favored the resurgence of populations

by increasing the rate of development and fecundity of surviving scales while reducing mortality from natural enemies. Population growth was retarded on hemlocks supporting high densities of feeding nymphs. These studies on distribution, alternate hosts, and dispersal establish a basis for predicting the rate of spread of *F. externa* in the Northeast. The investigations on the response of natural enemies to scale density and on the effects of insecticide treatment and of environmental- and herbivore-induced stress of hemlock on scale population growth provide a means for determining the most effective measures for controlling *F. externa* in the hemlock forest.

Sexual Interference as a Displacement Mechanism in *Aedes* (Diptera: Culicidae) Mosquitoes.—I. N. McDaniel and M. D. Bentley, Univ. Maine, Orono, ME 04473.

While conducting studies on oviposition attractants for *Aedes triseriatus* in a large cage, we found that the introduction of small numbers of *A. aegypti* led to a rapid collapse in the *A. triseriatus* population. Displacement by another species is generally regarded to be due to competition for food and space. However, in this case it appears to be due to sexual interference, since the males of *A. aegypti* were seen mating with the other species. These species do not hybridize, but it appears that the transfer of matrone from *A. aegypti* males prevents *A. triseriatus* females from mating with conspecific males. Proof of cross mating was established by finding sperm in spermathecae of *A. triseriatus* females caged with males of *A. aegypti*. These females had been isolated singly as pupae to prevent contact with conspecific males. Our data indicate that *A. triseriatus* cannot coexist with *A. aegypti* where the latter are present in cross mating, but in each case *A. triseriatus* was eliminated by the third generation. It is suggested that field releases of suitable strains of *A. aegypti* might result in eradication of isolated populations of *A. triseriatus* in areas where La-Crosse virus is enzootic. In northern areas, the *A. aegypti* would not survive the winter. Releases of males might suffice in the south.

Passive Dispersal of the European Skipper, *Thymelicus lineola* (Ochs.) (Lepidoptera: Hesperiidae), an Insect Pest of Hay Crops.—J. N. McNeil and R. M. Duchesne, Univ. Laval, Québec, P.Q. Canada.

The European skipper, *Thymelicus lineola*, has recently become a serious pest of hay grasses in several Canadian provinces and in the state of Michigan. As the adults are weak fliers the possible importance of passive

transport of eggs (containing diapausing 1st stage larvae) has been alluded to but never studied. Hay bales bought in an area of heavy infestation in 1975 were found to contain over 5,000 viable eggs/bale. This is considered a conservative estimate as egg mortality (≥50%) was considerably higher than in other years (≈20%), due to an extremely dry period following oviposition. Eggs infested by cattle did not survive. The possibility that certified timothy seed may contain eggs was also considered. The waste obtained following the post harvest cleaning process was heavily infested (2,000 eggs/kg) but the number found in the certified seed was negligible. However the waste is either sold or given away as uncertified seed. Considering the high densities of eggs and the wide scale movement of hay and uncertified seed we believe that the passive transport of *T. lineola* eggs is the principal means of dispersal for this pest. It is therefore recommended that all waste material from the certified seed cleaning process be destroyed, and that the possibility of limiting the shipment of hay from infested areas be considered.

Nocturnal and Diurnal Movements of Beneficial Insects in a Potato Field.—T. P. Mack and Z. Smilowitz, Pennsylvania State Univ., University Park, PA 16802.

The nocturnal and diurnal movements of the predaceous natural enemies of the green peach aphid, *Myzus persicae* (Homoptera: Aphididae) were investigated in potato (*Solanum tuberosum* L. var. *katahdin*) fields in order to develop a valid sampling scheme. These movements were determined by the weekly sampling of 36 clear flat plastic sticky traps during July and August. Each of the vertically aligned 91.5 × 21.0 cm sticky traps were placed 2 inches above the soil level. Counts of insects and their location on the traps were taken at three intervals between 2130–0930, 1030–1330 and 1415–1600 h. The most abundant predators found were coccinellids (Coleoptera: Coccinellidae), chrysopids (Neuroptera: Chrysopidae), and syrphids (Diptera: Syrphidae). The average number of coccinellids caught/h during the sample periods was 11.5 ± 16.09, 8.64 ± 4.52 and 19.85 ± 9.06. Smaller numbers of chrysopids and syrphids were found: 1.48 ± 1.48, 0.84 ± 0.49, 0.5 ± 0.5 and 0.4 ± 0.3, 1.56 ± 1.0, 1.5 ± 1.37. The least movement and variation for the coccinellids occurred during the 1030–1330 h sampling period, while the least movement for chrysopids and syrphids occurred during the 1030–1330 and 2130–0930 h periods, respectively. Seventy-six percent of the coccinellids caught were on the middle and lower trap heights (890/1,156) while 76.2% of the chrysopids (64/84) and 76.8% of the syrphids (53/69) caught were on the middle and upper trap heights.

Histoblasts: Localization and Growth Dynamics in the Young Larvae of *Drosophila melanogaster* (Diptera: Drosophilidae).—M. M. Madhavan, Univ. California, Irvine, and Holy Cross College, Worcester, MA 01610.

The freshly hatched *Drosophila* larva is a mosaic organism consisting of both the larval and imaginal cells. The presumptive integument of the adult head, thorax and genitalia is represented by imaginal discs and that of the adult abdomen by nests of cells, the histoblasts. The changes occurring in imaginal discs during postembryonic stages have been studied in great detail. However, information regarding the developmental changes occurring in the histoblasts during the early stages of postembryonic development is scanty. Furthermore, histologically, the presence of histoblasts in the newly hatched larvae has never been demonstrated. By histological techniques I have shown that each abdominal hemisegment of a young larva consists of an anterior dorsal, posterior dorsal and a ventral histoblast nest containing about 13, 6 and 12 cells respectively. The number of cells in each histoblast nest remains almost the same from the time of larval hatching until 5 h after pupariation when they begin to proliferate rapidly. This behavior is in contrast with that of the histoblasts of other dipterans studied in which they begin to divide during the second instar. The histoblasts increase in volume about 60-fold and their nuclei show an increase of about 25-fold between the time of larval hatching and pupariation.

A Review of Maple Bark Scale, *Cryptococcus williamsi* Krb. and Hale (Homoptera: Cryptococcidae), in New Hampshire.—A. H. Mason, Univ. New Hampshire, Durham, NH 03824

A new scale insect on sugar maple, *Acer saccharum*, was found in New Hampshire on December 30, 1965 following its initial discovery in Vermont during 1964. The scale was described by Michael Kosztarab and Dreamer L. Hale in 1967 and named *Cryptococcus williamsi* Krb. and Hale with a suggested common name, maple bark scale. Because of the recognized damaging association of beech scale, *Cryptococcus fagi-Nectria* to American beech and the importance of sugar maple to the economy of portions of the United States, cooperative and coordinated investigations were initiated by many state and federal agencies to establish the distributional limits, biology and host relationships of *C. williamsi*. Although the principal host of *C. williamsi* is sugar maple one observation was made of this scale on red maple, *Acer rubrum*. The maple bark scale was found to be widely distributed throughout New Hampshire. The maple bark scale was detected in association with a *Nectria* fungus with fruiting bodies similar to *Nectria coccinea* var. *faginata* Loh. of beech on two of 74 areas examined

in the White Mountain National Forest. Only five infected trees were observed. Parasites, *Coccophagoides* sp. (Aphelininae: Eulophidae), were reared from the maple bark scale. Although no immediate threat of a maple bark scale-*Nectria* association damaging to sugar maple is apparent, continued studies and investigations are recommended.

Emergence of Alfalfa Blotch Leafminer Adults, *Agromyza frontella* (Rondani) (Diptera: Agromyzidae).—W. K. Mellors and R. G. Helgesen, Cornell University, Ithaca, NY 14850.

The objective was to develop a predictive model of alfalfa blotch leafminer adult emergence. The leafminer overwinters in New York as puparia in the soil. Development in the spring proceeds as heat unit accumulation after warming of the soil. Laboratory incubation of nondiapausing pupae at constant temperatures provided developmental times and rates for males and females. Nonlinear developmental models were fit to the data. Developmental thresholds were less than 10°C. Females developed slightly faster than males at the same temperatures and required from 15 days at 25°C to 60 days at 10°C. Daily maximum and minimum soil temperatures were used as inputs to the developmental model to sum development over time and predict adult emergence in the field in the spring. Aside from sex differences in developmental rates, 3 factors tended to spread out the adult emergence of puparia in the soil, the changes in soil temperature with soil depth, and the distribution of developmental rates within the leafminer population. To account for this expected variability, the field population puparia were stratified by developmental rate, soil depth, and sex prior to estimation of individual emergence dates. These were combined into an overall emergence pattern.

In Vitro Rearing of Larval Southern Pine Beetles, *Dendroctonus frontalis* Zimmerman (Coleoptera: Scolytidae), on tissue-cultured loblolly pine callus. —R. L. Mott, North Carolina State Univ., Raleigh, NC 27607; H. A. Thomas, U.S. For. Ser., Research Triangle Park, NC 27709 and G. Namkoong, U.S. For. Ser., Raleigh, NC 27607.

Efforts to study the nutrition of the southern pine beetle have been prevented by our inability to rear it free of its normal microbial associates, some of which are thought to contribute to its nutritional requirements. Although attempted at various times in the past, development of an aseptic rearing technique has been unsuccessful. The objective of this study was to evaluate tissue-cultured callus of phloem from one of the beetle's prin-

cipal hosts, loblolly pine *Pinus taeda* L., for its ability to sustain larval growth and development. The results showed that aseptic beetles could be produced on callus on 3% agar and that the addition of β-sitosterol to the substrate enhanced the rate of development. Callow adults were obtained in 35–65 days at about 22°C. Approximately 17% of the larvae completed their development. Free moisture or higher temperatures were harmful. The adults were slightly smaller than normal and efforts to obtain mating have been unsuccessful so far. The results suggest that the relationship with the concomitant microorganisms is not obligatory if a sterol source is provided. The sterol content of unfortified callus has not been determined.

Isolation and Partial Characterization of Uric Acid Crystals Obtained from Cockroach Tissues (Dictyoptera).—D. E. Mullins, VPI and SU, Blacksburg, VA 24061.

Internal storage of uric acid in cockroaches has been observed by many workers. These internal reserves are apparently in a dynamic state since they are stored/mobilized in response to dietary nitrogen levels. There is evidence that uric acid is stored as urate salt(s) of K, Na and perhaps NH_4 because in many instances whole body uric acid content can be correlated with K, Na and nitrogen levels. Urate crystals have been removed and purified from cockroach tissues by tissue disruption in nonaqueous media and separated from cellular debris by filtration and centrifugation through immersion oil columns. Visual examination of the isolated urate crystals using light microscopy has revealed that they are round spherules, ranging from about 5–40 μm in diameter and display a characteristic birefringence under polarized light. Scanning electron microscopy revealed that although most of these crystals are smooth spherules, a few of them display a multilobed appearance. Results obtained using microprobe analysis indicated that the spherules were high in K, but Na content was low. Infrared spectra obtained from isolated spherule preparations displayed a characteristic pattern different from various urate standard preparations. Examination of these spherules using transmission electron microscopy indicate that they consist of a homogeneous matrix with a dense, dark-staining center which might be of importance in the initiation of urate crystal growth. Studies of the precise composition and the dynamics of urate storage/mobilization may provide useful information on the formation and growth of biological crystals.

Separation and Quantitation of the Norsequiterpenes from Gyrinid Defensive Secretions Using High-pressure Liquid Chromatography.—A. T. Newhart and R. O. Mumma, Pennsylvania State Univ., University Park, PA 16802.

High-pressure liquid chromatographic (HPLC) separations of the gyrinid norsequiterpenes, isogyrinidal, gyrinidal, gyrinidione and gyrinidone have been developed. Good separations were achieved with a normal phase column (μPorasil) using a choloroform:hexane solvent system and for a reversed phase column (μBondapak C_{18}) using an acetonitrile:water solvent system. These methods were rapid, sensitive, stable and suitable for quantitative studies. The applicability of these methods was demonstrated when the norsequiterpenes of the defensive secretions of the aquatic beetle *Gyrinus frosti* were isolated and identified as isogyrinidal and gyrinidal. The defensive titer of *G. frosti* and *Dineutus assimilis* were studied over a 5-month period. A large variation exists in the defensive titer between individuals of the same species, and the average titer of a species fluctuates seasonally.

Host Finding and Trapping of European Apple Sawfly, *Hoplocampa testudinea* (Hymenoptera: Tenthredinidae).—E. D. Owens and R. J. Prokopy, Univ. Massachusetts, Amherst, MA 01003.

The European apple sawfly (EAS) is one of the 5 major pests of apple fruits in southern New England. Little is known of its behavior, and until now, there has been no effective method of monitoring EAS adult populations. On sunny warm days, we studied EAS behavior in unsprayed blooming apple trees. We observed extensive pollen feeding at the anthers and oviposition at the distal end of the flower rceptacle. EAS flew frequently, usually landing directly on or beside blooms. Spectrophotometric analysis revealed very low reflectance of any floral components from 300–370 nm, gradually rising reflectance of the petals and stamens from 370–450 nm, and high reflectance of the petals from 450–650 nm (insect-visible spectrum —300–650 nm). Comparisons of EAS responses to 15 × 20 cm sticky coated rectangles hung in the trees showed high EAS captures on zinc oxide and titanium oxide white (both with reflectance spectra very similar to apple blossom petals), some captures on gray and clear plexiglas, and few or no captures on lead carbonate white and aluminum foil (differing from apple blossom petals due to higher reflectance from 300–370 nm). Yellow, green, blue, orange, red and black also captured few EAS. We consider sticky coated zinc or titanium oxide white rectangles to be a promising EAS monitoring device.

Efficacy of Selected Pesticides Against *Hemerocampa leucostigma* (Smith and Abbott) (Lepidoptera: Lymantriidae).—M. P. Parrella and R. L. Horsburgh, Shenandoah Valley Res. Sta. VPI and SU, Steeles Tavern, VA 24476.

The white-marked tussock moth, *Hemerocampa leucostigma*, was found heavily infesting approximately 300 acres of mature apple trees in Syria, Virginia, during 1976–77. Workers refused to enter the orchard to pick fruit or to remove water sprouts because of skin irritations produced by the hairs of the larvae. In an effort to control this insect with conventional pesticides, we found that current toxicity data for *H. leucostigma* was lacking. As a result, laboratory tests using a number of orchard pesticides at their current recommended dosages were conducted. The following pesticides were evaluated: Guthion 50 WP, Imidan 50 WP, Thuricide HPSC WP, Penncap M 22%, Dipel WP, Lannate L 24% and Dikar WP. These materials can be separated into 2 groups based on the mortality produced. Group I consisted of Guthion, Penncap M and Lannate which consistently resulted in the highest mortality while showing no significant differences among themselves. The second group, made up of Dipel, Thuricide, Imidan and Dikar, produced mortality significantly greater than the control at all recordings past 24 h. However, this mortality was significantly smaller than Group I at all the readings. Dikar, a fungicide and miticide, produced higher mortality at 48 and 72 h than the other members of Group II. To obtain the greatest kill in the shortest period of time, any pesticide in Group I would be satisfactory.

Possible Character Divergence of Mandible Size and Gape in Sympatric Tiger Beetles (Coleoptera: Cicindelidae).—D. L. Pearson and E. J. Mury, Pennsylvania State Univ., University Park, PA 16802.

Evidence is presented for character divergence in mandible size in seventeen sympatric species of tiger beetles occurring in the Sulphur Springs Valley, Arizona. Feeding trials demonstrate that mandible length is important in determining the upper limit of a cicindelid's prey range. Mandible size may thus be used as an indicator of resource partitioning within the tiger beetle community. Grassland and pond edge habitats are compared. The former supports a meager prey fauna with a considerable size range. The latter contains many prey items of relatively uniform size. Considerable interspecific overlap in both mandible and body lengths is found among species that forage regularly near a permanent pond site. Spatial separation of tiger beetles along the pond edge is likewise minimal. In contrast, grassland cicindelids fall into three size classes—each containing two

species. These pairs can be delineated further on the basis of microhabitat preference, diurnal activity patterns, and prey specificities. Similar divergence occurs among those species occupying marginal habitats or temporary pond edges. Selection for character divergence in areas of probable food limitation has apparently acted to reduce niche width, resulting in the lessening of competitive pressures.

Monitoring Traps for Tarnished Plant Bug, *Lygus lineolaris* (Hemiptera: Miridae), on Apple.—R. J. Prokopy, R. G. Adams and K. I. Hauschild, Univ. Massachusetts, Amherst, MA 01003.

Adult tarnished plant bugs (TPB) are one of the 5 major pests of apple fruit in New England. Until now, there has been no reliable method for accurately monitoring TPB population levels on apple. Therefore, we compared TPB responses to various hues and shades of 15 × 20 cm sticky-coated rectangles hung from apple tree branches ca. 1 m above ground. Titanium oxide white enamel, clear Plexiglas and Zoecon daylight fluorescent yellow cardboard (ZFY) captured equal numbers of TPB and more than gray, yellow, green, blue, orange, red, or black enamel, aluminum foil, or daylight fluorescent green or orange. Aided by spectrophotometric analysis, we interpret these findings to suggest lack of positive response of appetitive TPB to ultraviolet-reflecting surfaces (analogous to skylight) and surfaces of dark color (analogous to apple twigs and bark). Weekly, from green tip to harvest, we sampled TPB injury on 12 apple trees receiving no insecticidal sprays. On each sampling date on each tree, we also compared 3 methods of monitoring TPB populations: 1) 25 net sweeps of the ground cover under the tree; 2) observation of 25 apple buds or fruits for presence of individual TPB; and 3) number of TPB captured that week on 1 ZFY trap. The first 2 methods proved of little value, since very few TPB were found. The traps captured considerable TPB and proved a useful monitoring device in that fluctuations in TPB trap captures showed high positive correlation with fluctuations in occurrence of TPB injury.

Development of the Esophageal Bulb of the Apple Maggot *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae).—S. Ratner and J. G. Stoffolano, Univ. Massachusetts, Amherst, MA 01003.

The esophageal bulb, a possible mycetome of adult *R. pomonella* first appears 8–11 days post-pupation as a simple undifferentiated bud from the foregut, just posterior to the pharynx. By 7–10 days preeclosion, the apical cells of the bulb become elongate, contorted, and basophilic. A thin

intima surrounds the lumen. There are no ultrastructural indications of functional specialization. By 5–6 days preeclosion, the apical cells are tall and columnar, while the remainder of the epithelium retains a low cuboidal form. The proximal third of the bulb is constricted into a neck by a developing layer of circular muscle. The apical membranes of the columnar cells are thrown into folds, with numerous mitochondria and microtubular bundles interspersed among them. There are no significant changes in the morphology and ultrastructure of the bulb from emergence until sexual maturity (2–3 weeks posteclosion), when mitochondrial degeneration becomes apparent. The ultrastructure of the esophageal bulb supports the hypothesis that the apical epithelium absorbs small molecules from the lumen.

Contact Toxicity of Selected Insecticides to Gypsy Moth *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae) Larva; Larval Parasite, *Compsilura concinnata* Meigen (Diptera: Tachinidae); and Pupal Parasite, *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae).—N. C. Respicio and A. J. Forgash, Rutgers Univ., New Brunswick, NJ 08903.

An estimate of the hazards of gypsy moth control materials to parasites can be obtained by comparing the amount required to kill the host with those that are lethal to the parasite. This investigation deals with the relative toxicity of 7 insecticides to third-instar gypsy moth larvae; larval parasite and pupal parasite. The insecticides were evaluated by topical application. Results show that both parasites were significantly more tolerant to trichlorfon, FMC 33297 and SBP 1513 than third instar gypsy moths. Male and female *B. intermedia* were significantly more tolerant to these three compounds than *C. concinnata*. *C. concinnata* were highly tolerant while *B. intermedia* were as susceptible as third instars to acephate and carbaryl. Although CGA 18809 was significantly toxic to third instars, it was also highly toxic to *B. intermedia*. On the other hand, Accothion® was least toxic to third instars but was highly toxic to both species of parasites. Since trichlorfon, FMC 33297 and SBP 1513 were relatively more toxic to gypsy moth larvae and were significantly less toxic to both species of parasites, these compounds are potentially much less hazardous to both parasites than any of the insecticides tested. These data provide information on the inherent toxicities of the various insecticides to a given parasite species and on the differences in insecticide susceptibility between species.

Method for Assaying Nectar Sugars Produced by Plants and Harvested by Insects.—R. B. Roberts, Rutgers Univ., New Brunswick, NJ 08903.

The energetic relationships between plants and nectar gathering insects is basic to studies of foraging behavior, as well as to the applied aspects of crop pollination and honey production. The standard microcapillary technique for assaying nectar for sugar is inaccurate and tedious. Furthermore, it is useless for plants with minute flowers, such as the Compositae, or plants with very viscous nectar, such as cranberries. The colorimetric method for assaying microgram amounts of sugar in solution developed by Dubois, et al. has been adapted for determining the amounts of sugar produced by plants and harvested by insects. The procedure is basically as follows: 1) rinse flower (or macerated insect) in known amount of water and merthiolate; 2) place 1 ml rinse soln in test tube; 3) add 1 ml 5% phenol soln; 4) add 5 ml conc H_2SO_4; 5) measure absorption of soln at 480–490 mμ with spectrophotometer. Reagents are inexpensive, relatively stable, and universally available. Hundreds of samples may be assayed per day. The technique has been used to measure: 1) total sugar production in 4 different types of plants; 2) rate of sugar production in these plants; 3) total sugar harvested by insects; 4) rate at which insects harvest sugar; 5) harvesting efficiency of individual insects.

Alternate Methods of Cockroach Control: Genetic.—M. H. Ross, VPI and SU, Blacksburg, VA 24061.

Genetic studies have laid the foundation for investigating genetic control of the German cockroach, *Blatella germanica* (L.). Reciprocal translocations were selected as the most promising of the available mechanisms. The genetic load imparted by single translocation-carrying males cannot alone suppress population growth, but double translocation heterozygotes have this capability. Their effectiveness depends on a combination of lethality derived from unbalanced gametes and sterility arising from embryonic trapping (inability of low numbers of viable embryos to force open the ootheca at the time of hatch). Synthesis and study of 3 double translocation stocks showed similar properties in 2 which combined independent translocations, including 70% sterility from trapping. Males of the third double stock, a 3-chromosome type, showed sterility in 90% of the oothecae in crosses to wild-type females. All 3 showed equal competitiveness with laboratory wild-type males in 1:1 mating tests. Sequential releases of 4-chromosome double males suppressed growth of a laboratory population. However, the 3-chromosome double is a better

mechanism, due both to higher sterility and to progeny genotypes (all are translocation heterozygotes). The establishment of productive intercross systems as sources of double males with considerably higher lethality and sterility than in the parental matings is possible due to sex differences and changes in the frequencies of alternate vs. adjacent chromosome disjunction. The 3-chromosome double approaches complete sterility but other stocks currently on hand may be manipulated to achieve this goal which is estimated to occur at ca. 80% lethality.

Varietal Preferences of the Eastern Raspberry Fruitworm *Byturus rubi* Barber (Coleoptera: Byturidae).—G. A. Schaefers and B. H. Labanowska, NYS Agric. Expt. Sta., Geneva, NY 14456.

Bud feeding damage by adults was evaluated among 30 replicated varieties of red raspberries for 2 seasons. Bud damage, which is frequently overlooked by growers, exceeded 25% with certain varieties. Generally, percent injury was related to earliness of fruiting. This is characteristic of the first fruiting period of "fall-bearers." Exceptions included 'Indian Summer' which was lightly damaged. 'Heritage' was also lightly damaged, but this "fall-bearer" is an exception to the early fruiting characteristic. Late-fruiting "summer" varieties generally sustained less severe injury. An exception was the variety 'Latham.' Larval infestation levels were determined in the same planting for 4 seasons. Infestation in some varieties exceeded 40%. In general, the earliest fruiting varieties had the highest infestation levels. Adult concentration on these varieties would account for increased oviposition and the resulting larval infestation. No variety appeared to offer useful levels of resistance to the larvae. The results indicate that annual cropping of "fall-bearing" varieties would provide an escape from this pest problem.

Influence of *Myzus persicae* (Sulzer) (Homoptera: Aphididae) Infestations of Flue-cured Tobacco Yield and Quality.—P. J. Semtner, VPI and SU, Blackstone, VA 23824.

The effects of time and rate of green peach aphid, *Myzus persicae* (Sulzer), infestation on flue-cured tobacco yield and quality was investigated in Virginia during 1976. Experimental tobacco was artificially infested with nymphal and apterous adult aphids. Artificial infestations were made at 3, 5½ and 8 weeks after transplanting. Two separate releases were made 8 weeks after transplanting. The first received 50 aphids/plant and corresponded to release levels in the 3- and 5½-week post-transplant releases, while the second received 500 aphids/plant. The artificial

releases were compared to a natural infestation and to a treatment where aphids were controlled using foliar applications of malathion. Aphid populations increased rapidly on tobacco infested at 3 and 5½ weeks after transplanting and on naturally infested tobacco. Populations in the two 8-week post-transplant releases remained near release levels before beginning to decline 2–3 weeks after infestation. Aphid populations on the naturally infested tobacco declined more rapidly than did those on tobacco infested 3 and 5½ weeks after transplanting. Tobacco infested at 5½ weeks had 15% lower yield and value/ha than the control, while the 3-week post-transplant treatment had 6 and 9% lower yields and value/ha, respectively, than the control. These two treatments had significantly lower yield and values/ha than the other treatments, which were not significantly different. Tobacco infested at 3 weeks after transplanting had a value of 4 to 9¢/kg lower than the other treatments.

The Attack Response of *Efferia tricella* (Diptera: Asilidae) to Eight Tiger Beetle Species (Coleoptera: Cicindelidae).—T. E. Shelly and D. L. Pearson, Univ. Delaware, Newark, DE 19711 and Pennsylvania State Univ., University Park, PA 16802.

Past studies of the predaceous habits of adult asilids have generally been simple listings of prey species. More recently, asilid/prey size relationships have been quantified, yet for only one asilid species has prey recognition and hence relative vulnerability among prey items been examined. The overlap in temporal and spatial distribution between *Efferia tricella* and eight tiger beetle species indicated the importance of morphological and/or behavioral predator avoidance adaptations. Based strictly upon morphological characteristics, the vulnerability of the various beetle species was measured by recording (as strike or non-strike) the responses of individual asilids to tethered beetle specimens. The results indicated (1) asilid attack response was inversely correlated with body size and (2) the orange abdomen characteristic of two beetle species reduced strike frequencies below that observed for similarly sized specimens with black abdomens. Coating the orange abdomens with black paint resulted in increased strike frequencies, and conversely application of orange paint to a species with a black abdomen reduced strike frequency by nearly half. Thus, in a situation in which prey do not avoid predation by escape in time or space, large body size and orange coloration appear to effectively reduce asilid predation. These findings contribute toward an understanding of those factors which elicit asilid attacks and the subsequent vulnerability of potential prey items which necessarily underlies all comparisons of actual and available prey.

Evolution of Reproductive Isolation Between the Neotropical Butterflies *Anartia fatima* F. and *A. amathea* (Lepidoptera: Nymphalidae).—R. E. Silberglied and A. Aiello, Harvard Univ. and Smithson. Trop. Res. Inst., Box 2072, Balboa, Canal Zone.

The final event in true speciation is the evolution of prezygotic isolating mechanisms that prevent interspecific mating. Two species of *Anartia* that hybridize naturally in eastern Panama were studied by laboratory hybridization, including all possible backcrosses and F2 combinations of the 2 reciprocal F1 hybrids to the parental species and to one another. Strong postzygotic isolation in the form of hybrid breakdown, slower larval development and anomalous mating behavior, were observed in the second generation. Butterflies from sympatric and allopatric populations were then examined for the presence or absence of behavioral (prezygotic) isolating mechanisms. The results, compared with random samples of these species and their hybrids from the area of sympatry in eastern Panama, demonstrate the evolution of behavioral isolation where the 2 species occur together.

Sampling and Distribution of Potato Leafhopper Nymphs in Alfalfa.—D. E. Simonet and R. L. Pienkowski, VPI and SU, Blacksburg, VA 24061.

A sampling technique using quart ice cream cartons containing ca. ¼″ vapona squares was used to sample potato leafhopper nymphs in alfalfa. Laboratory tests showed that 91.1% of potato leafhopper nymphs can be easily extracted from groups of 3 stems after 24 h exposure in the cartons. Using this technique, stems were collected in two fields in Montgomery Co., VA to determine distributional patterns of potato leafhopper nymphs in alfalfa. The basic sampling unit was a 3 stem bouquet. Eighty groups of 3 stems were collected from each field at least every 2 weeks. Samples were counted and instar determinations were made in the laboratory. During most sampling periods there were not enough frequency classes in the population data to test distributional patterns. However, those data which could be tested showed that nymphs were distributed in an aggregated pattern following the negative binomial model. Sample sizes were determined based on this model using the coefficient of variation as a reliability parameter for levels of accuracy at 10, 20, and 30% of the mean. This technique is useful since samples can be quickly collected in the field, and nymphs can be easily counted and separated to instar in the laboratory.

Effects of the Nuclear Polyhedrosis Virus of *Lymantria dispar* (L.) [Lepidoptera: Lymantriidae] on the Endoparasite *Apanteles melanoscelus* (Ratz.) [Hymenoptera: Braconidae]: an Ultrastructure Study.—R. P. Smith and J. B. Simeone, SUNY College of Environmental Science and Forestry, Syracuse, NY 13210.

Fourth instar gypsy moth caterpillars containing the endoparasite, *Apanteles melanoscelus*, were fed an artificial diet containing 107 polyhedral inclusion bodies. After 10 days, endoparasites were dissected from their hosts and processed for light and transmission electron microscopy in the following manner: midguts or diced *Apanteles* larvae were fixed for 2 h in cold 1.5% glutaraldehyde in Sorenson's phosphate buffer (pH 7.2) with sucrose added, washed in buffer and post-fixed for 3 h in 2% osmium tetroxide. Tissues were stained overnight in 1% uranyl acetate, dehydrated in a graded series of ethanols and embedded in Spurr's resin. Sections were cut on a Porter-Blum MT-2 ultramicrotome and post stained with lead citrate. A Zeiss Universal microscope was used to examine thick sections while an RCA EMU-4 electron microscope operated at 100 kv examined adjacent sections. Optical and electron micrographs revealed polyhedra associated with host tissue fragments in the parasite midgut. Also, polyhedra and isolated nucleocapsids rest among the microvilli projecting into the lumen. In the hemocoel, polyhedra were enclosed within degenerating fat and blood cells of the parasite. Here, some polyhedra exhibited the densely stained periphery indicating they were formed within virus infected tissues. The mechanism by which polyhedra penetrated into the hemocoel is unknown, although abnormalities in the parasite nuclei and cytoplasm of the midgut suggest that the host disease may adversely affect the parasite.

The Effectiveness of Chlorofluorocarbon and Hydrocarbon Propelled *d*-phenothrin in Aerosols Against Biting Flies.— W. N. Sullivan and B. M. Cawley, Beltsville Agri. Res. Center, ARS, USDA, Beltsville, MD 20705.

The Beltsville Agricultural Research Center, Beltsville, MD, has been interested in the developing family of pyrethroid insecticides since Schechter and LaForge synthesized allethrin. Sumithrin (*d*-phenothrin) (3-phenoxybenzyl *d-cis* and *trans* 2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate), one of the newest pyrethroids, was selected for this study because it has excellent environmental qualities. Two aerosol formulations were prepared commercially: (1) 2% *d*-phenothrin in chlorofluorocarbons 11 + 12 (1:1), and (2) 2% *d*-phenothrin in H_2O, liquid propane/isobutane, and an emulsifier. Both formulations, when applied at a dosage of 0.91 to 1.2 g in

28.3 m^3 chambers (no air conditioning) gave a 96–100% mortality of *Anopheles stephensi* Liston, *Aedes aegypti* (L.), *Culex pipiens quinquefasciatus* Say, and *Stomoxys calcitrans* (L.). Both formulations at 5 g/28.3 m^3 gave a 100% mortality of *Tabanus lineola* Fabricius. In actual and simulated aircraft disinsection tests (complete air exchange every 3–4 min) a 5 g/28.3 m^3 dosage of formula 1 gave a 100% mortality of *Glossina morsitans* Westwood and *Simulium vittatum* Zetterstedt. The proposed Environmental Protection Agency rules prohibiting the use of chlorofluorocarbons as propellants in self-pressurized containers grants essential-use exemptions to flying insect pesticides for use in nonresidential food handling establishments and poultry coops; and for space spraying of aircraft.

Fine Structure of the Fat Body of *Aedes aegypti* L. (Diptera: Culicidae) During Vitellogenesis.—T. M. Tadkowski, Univ. Maryland, College Park, MD 20742.

An increasing number of biochemical studies concerning the extraovarian synthesis of vitellogenins have prompted a morphological investigation into the ultrastructure of the fat body of female *A. aegypti* during vitellogenesis. The adipocytes contain many large lipid droplets, numerous mitochondria large fields of glycogen, protein inclusions, microtubules and numerous free ribosomes, but possess very little rough endoplasmic reticulum (RER) at the time of adult emergence. After a 4-day starvation period (water only), the lipid and protein content is diminished, and cytolysosomal figures appear in the fat body cells. Seven hours after the female takes a blood meal, the oocytes begin rapidly filling with protein yolk, and the adipocytes begin to form additional RER, and large prominent nucleoli appear. The oocytes contain a significant amount of RER and numerous free ribosomes during the first 14 h post blood-meal, which suggest that the fat body may not be the only source of protein yolk during the early stages of vitellogenesis. The adipocytes synthesize increasingly larger amounts of RER during the next 17 h, although no storage of protein was seen. Starting at 24 h and continuing to 35 h after the blood-meal the flocculent material in the RER cisternae seems to pass into Golgi-like complexes. By 48 h post blood-meal, adipocytes possess little RER but contain numerous mitochondria. They both surround the nucleus. The nucleoli appear to "fragment" at this time. Many cytolysosomes, substantial amounts of glycogen and large clear areas in the cytoplasm are also present.

Initial Field Tests Using Commercial *Bacillus thuringiensis* Berliner to Control the Variegated Leafroller *Platynota flavedana* Clemens (Lepidoptera: Tortricidae).—J. H. Thomas & C. H. Hill, VPI and SU, Winchester Fruit Res. Lab., Winchester, VA 22601.

In 1974, the variegated leafroller, *Platynota flavedana*, damaged 47.2% of the unsprayed apples in an orchard in Winchester, VA. Control of the pest was attempted using dilute sprays of 4 different treatments of *Bacillus thuringiensis* (Thuricide 16B 8 BIU, Thuricide HPC 8 BIU, Dipel 7.26 BIU, Dipel 3.63 BIU/100 gal). Each treatment was applied to 5 single tree replicates at 2-week intervals starting on July 8 and ending Sept 9. The treatments were evaluated in Aug and Sept by timed counts of larval habitats and at harvest by examination of the fruit. The number of apples damaged ranged from 4.8% for Thuricide 16B to 12.4% for Thuricide HPC. In the same orchard *P. flavedana* larvae damaged 46.4% of the untreated apples in 1975. Dilute treatments of *B. thuringiensis* were applied at 2-week intervals beginning June 17 and ending Aug 27. The experimental design was the same as in 1974. Evaluations of the treatments were made by examining the contents of 50 leafrolls per tree (or as many as could be found) in Aug and Sept, and by examination of the apples at harvest. The amount of damage ranged from 0.8% for Dipel at 7.26 BIU to 7.2% for Thuricide HPC at 8 BIU/100 gal. The combination of Thuricide HPC 4 BIU + Fundal SP .25 lb/100 gal restricted the damage to 1.6% of the apples examined. These results suggest that experimentation with *B. thuringiensis* be continued to determine the proper rates, formulations, combinations with other materials, and timing of applications to control *P. flavedana*.

Laboratory Evaluation of the Synthetic Pyrethroid Ectiban (Permethrin) for Control of *Musca domestica* L. (Diptera: Muscidae).—L. Townsend, Jr. and E. C. Turner, Jr., VPI and SU, Blacksburg, VA 24061.

Ectiban was evaluated as a feed additive, larvicide, residual surface spray, and treated cotton cords for potential use in caged-layer poultry houses. Ectiban at 5 and 10 ppm ai in larval media controlled 1st and 2nd-instar fly larvae. However, an encapsulated formulation of the pyrethroid fed to hens did not produce comparable results. A bioassay of acetone extracts of feed samples from a test bird indicated that most insecticidal activity was lost in the small intestine. Fly production was greatly reduced in trays of manure seeded with fly eggs following topical applications of the pyrethroid at 24, 48 and 96 mg ai/ft^2. A wettable powder and emulsifiable concentrate were sprayed on unpainted, latex- and enamel-painted plywood panels and styrofoam at the rate of 2 mg ai/ft^2. Residual

performance of the two formulations on these surfaces was compared by exposing adult flies to the unweathered panels after selected time periods. The EC was ineffective on the painted panels. The WP was effective on latex for 30 days and on enamel for 45 days. Both formulations remained toxic on styrofoam and unpainted plywood for over 50 days. Caged flies were exposed for 1 h to cotton cords treated with 1% or 5% ECTIBAN. Mean percent knockdowns were 76 and 95; mean percent mortalities after a 24 h recovery period were 45 and 61, respectively. ECTIBAN is a potent insecticide. It demonstrated a potential as a tool in the pest management of fly pests in poultry houses.

Comparison of Thistle-reared Versus Diet-reared *Ceuthorrhynchidius horridus* (Panzer) (Coleoptera: Curculionidae).—J. T. Trumble and L. T. Kok, VPI and SU, Blacksburg, VA 24061.

Subsequent to the development of nutritionally adequate diets, comparisons (*t*-test at 1% level) were made between weevils raised on diets and on musk thistle rosettes. Differences in egg sizes were not significant. Egg viability ranged from 69.0% (plant-reared adults) to 79.7% (diet-reared adults), indicating that diet-reared weevils are as fertile as those reared on musk thistle. A diet-reared ♂ mated with a plant-reared ♀ produced eggs with a 70.0% hatch rate. First instar head capsule widths were not significantly different for larvae from diet-reared versus plant-reared adults. Although 28 day old larvae from rosettes weighed significantly more than those from diets, the latter were not significantly different from larvae produced from plants in a previous study. This suggests: 1) a deviation in host suitability between rosettes used for this and the previous test; 2) that variation in larval growth rates requires large sample sizes for statistical accuracy; 3) dissimilar environmental conditions (other than temperature) could have affected larval developments; or 4) a combination of the preceding. Comparison of adult sizes revealed that plant-reared weevils were significantly larger than diet-reared weevils. Although environmental conditions for adult development were different, smaller adult sizes resulting from diets imply nturitional defects in the artificial media. This apparent defect remains the foremost obstacle to a "mass" production program for *C. horridus*.

The Importance of the Lesser Appleworm, *Grapholitha prunivora* (Lepidoptera: Olethreutidae) in New Hampshire Apple Orchards.—J. P. Turmel and G. T. Fisher, New Hampshire Agri. Expt. Sta., Durham, NH 03824.

During the months of April through September 1975, a study was conducted on the occurrence, distribution and adult population levels of certain apple Tortricids and Olethreutids in NH. Based on data received from the fruit infestation studies, the lesser appleworm can be considered an economic threat of apple in NH. In abandoned orchards, the population density of this species is extremely high. An average of 10.8% of the surveyed fruit on July 25, 1975 were infested by the lesser appleworm. This, when compared to the known economic species from previous records of the red-banded leafroller and the codling moth, where infestation levels were 1.42% and 8.59% respectively, shows the lesser appleworm to be a genuine economic threat potential. In harvested apples of September, the lesser appleworm infested 22.4% of the evaluated fruit while the red-banded leafroller and the codling moth infested 7.33% and 27.84% respectively. The potential for economic damage to an orchard is definitely present with the existence of the lesser appleworm in NH. Fortunately, present spray programs coincide with the adult flight periods. If present spray programs of apple in NH are altered or changed without consideration of the lesser appleworm, severe infestations by this olethreutid could cause heavy economic losses to the NH orchardist.

Breeding Habitats of *Culicoides* (Diptera: Ceratopogonidae) and Factors Affecting their Development.—E. C. Turner Jr., VPI and SU, Blacksburg, VA 24061.

Worldwide interest in the genus *Culicoides* has been increasing. These annoying biting midges have been reported to transmit a number of diseases in mammals and birds. Investigations of their breeding habitats show that the larvae live in a variety of aquatic and semi-aquatic substrates. These studies consist not only of general descriptions of breeding sites but also the physical, chemical and nutritional characteristics of the substrates. Attempts have been made to group species by these habitat types. Factors that affect larval development are moisture, temperature, diet, and physical properties of the substrate. Low temperature slows larval development and high temperature causes some species to go into aestivation. Microorganisms commonly found in the habitat site must be available. Proper substrate is necessary to provide cover and protection. Intensity and length of light can also be a factor.

Determination of Constant Temperature Developmental Thresholds for *Myzus persicae* (Sulzer) (Homoptera: Aphididae).—M. E. Whalon and Z. Smilowitz, Pennsylvania State Univ., University Park, PA 16802.

An initial step in dynamic-deterministic model building has been to derive the function(s) relating physiological development of an insect to a measurable environmental parameter(s). Degree days centigrade (°D) unite insect development to a temporal-heat unit parameter. °D have been calculated in many ways, but the computerized, modified sine wave technique provides one of the most accurate. Utilization of this technique requires the determination of both lower (LDT) and upper (UDT) developmental thresholds. Three temperature regimes were programmed in constant temperature chambers for the LDT (3, 5 and 7 ± 1°C) and the UDT (29, 31 and 33 ± 1°C). Ninety-eight first instar *M. persicae* were individually maintained in each regime on 1.5 cm potato leaf discs (*Solanum tuberosum* L. var. *katahdin*) floating in a potassium-nitrogen-phosphorus solution. Longevity, duration of nymphal stadia and offspring produced were recorded every 8 h. The LDT was 4 ± 1°C as development occurred at 5°C, but not at 3°C. At 5°C, 5% of the test aphids reached the adult stage, producing 15 offspring (1.66 offspring/individual). The mean instar period at 5°C was 34.68 ± 2.771°D. Mean instar period at 7°C was 33.77 ± 2.940°D, with 46% reaching maturity (7.33 offspring/individual). The UDT was 30 ± 1°C since maturation and reproduction occurred at 29°C but not at 31 or 33°C. At 29°C the mean instar period was 32.70 ± 1.916°D and 13.9% of the individuals reproduced (2 offspring/individual).

Relative Toxicity of Five Insecticides to Larvae of *Dermacentor variabilis* (Say) (Acarina: Ixodidae).—D. J. White and J. L. Benach, New York State Health Dept., Health Sciences Center, SUNY, Stony Brook, NY 11794.

The toxicity of 5 insecticides to *D. variabilis* larvae was tested by exposing the larvae to treated surfaces. LC and LC values, derived by probit analyses, showed that noled was approximately 100 times more toxic to larvae than either propoxur, chlorpyrifos, or pyrethrins and 1,000 times more toxic than ronnel. The LC values in ppm of noled, propoxur, chlorpyrifos, pyrethrins and ronnel at 24 h were, respectively, 0.025, 0.635, 2.394, 2.645 and 24.700. These representative data indicate that the concentrations of insecticide surface residues effective for larval control in the laboratory were less than concentrations recommended by the pesticide manufacturers for field applications to other arthropods. Any insecticide concentration capable of controlling *D. variabilis* adults will also provide significant larval mortality if the application for adult ticks is made to coincide with peak

larval populations. Optimally-timed field applications aimed to immature stages of the tick can contribute to the reduction of the total tick population in subsequent years. Prior to establishing recommendations for field applications of pesticides for tick control, further experimentation is necessary on the toxicity of these and other chemicals on *D. variabilis* adults.

Pesticide Resistance in Field Populations of German Cockroaches (Dictyoptera: Blattellidae).—F. E. Wood, Univ. Maryland, College Park, MD 20742.

Field resistance of German cockroaches reflects the same symptoms as some other facets of cockroach population behavior, e.g. pesticide misapplication; bad sanitation; reinfestation from uncontrolled areas; differential pesticide breakdown from heat, temperature, incompatible surfaces, etc. All of these conditions are found in urban situations such as public housing. Factors contributing to selection for resistance are large cockroach populations, regular pesticide exposure, variable dosages, unsprayed areas and a routine method of exposing cockroaches to sprayed surfaces. These factors translate into action in the following ways: 1) implementation of vigorous unbending spray schedules (regular exposure), 2) untrained applicators (unsprayed areas, variable dosage), 3) no application in some units (unsprayed areas), 4) routine flushing (method of exposing cockroaches to pesticide) driving some insects into refuges. This action results in a "resistance mill." Similar factors can facilitate the selection for "behavioral resistance" simply if a cockroach is stimulated to activity when it finds itself on a treated surface. Behavioral resistance, which is hard to quantify and recognize, obfuscates a situation where incomplete application or any level of physiological resistance exists. Where an immense cockroach population builds up due to pesticide resistance it seems to take on individual characterizations such as pesticide resistance, while surrounding populations are susceptible; harborage becomes very important; movement into light and out of doors; and aggregating areas. Whether this behavior is due to increased population or not, it raises questions of territoriality, some hierarchy formation or aggression and communication.

Present Status of Cockroach Resistance and Control: the Pest Species and Their Habitats.—C. G. Wright, North Carolina State Univ., Raleigh, NC 27607.

The German cockroach, *Blattella germanica* (L.), is the dominant domestic species throughout the United States and most other countries. It occurs in

residences, restaurants and many other structures, where it prefers food preparation-serving areas. Three other species, the American cockroach *Periplaneta americana*, the Oriental cockroach *Blatta orientalis* and the brown-banded cockroach *Supella longipalpa*, are also encountered. Americans are often found in the lower confines of structures, especially where warm, damp conditions exist, e.g., in basements of industrial and commercial buildings, steam tunnels and sewers. Orientals prefer crawl areas, basements and damp areas of buildings. Brown-bandeds occur in kitchens, bedrooms, and all other rooms of residences, and occasionally in office buildings, research laboratories and other buildings. Other cockroach species, such as the brown *Periplaneta brunnea*, the smoky-brown *Periplaneta fuliginosa* and the Australian *Periplaneta australasiae*, can infest structures in large numbers. Heavy infestations depend upon the availability of water, food, and shelter; water is the most critical factor for a large population buildup. Brown-bandeds may be an exception to this condition. Sewers can be the locus for structure infestation and reinfestation, especially by American cockroaches. All species, possibly excluding the brown-banded cockroach, can live outdoors in many areas in warmer months, providing a constant source of reinfestation.

Preliminary Studies of Adult Beetle Populations and Their Bioseasonal Distribution on Natural Vegetation.—W. L. Young and B. R. Rao, East Stroudsburg State College, East Stroudsburg, PA 18301.

The enumeration and seasonal study of insect populations has been studied in detail since the turn of the century. Most work on arthropod populations on natural vegetation is the result of large scale investigation. Variation in the beetle population was studied during the 1975–76 season on the inflorescence of the natural vegetation of a specific area. The peak periods of diurnal activity in the upper herb stratum could be correlated to the subseasonal progress of certain flowering plants. Samples were obtained by the standard sweep net collections and identified to their families and to species in some cases. Following generalizations were made: 1) The fluctuations of different species of beetles may be attributed to the bioseasonal changes in the number of predominant species of flowering plants. 2) The advance, peak and decline of several populations were associated with the floral production of the plant species. 3) The duration of occurrence of certain important beetles as units, together with the appearance of floral succession can be divided into biotic seasons. The studies also reveal the probable alternative host plants of several beetles of some economic importance.

THE EPIZOOTIOLOGY OF SOME TICK-BORNE ARBOVIRAL DISEASES

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The World Health Organization (1967) defines an arbovirus as a virus which is "maintained in nature principally, or to an important extent, through biological transmission between susceptible vertebrate hosts by haematophagous arthropods . . . ." Thus, the term "arbovirus" is an ecological, rather than a taxonomic, classification. There are 334 proven or suspected arboviruses registered in the latest edition of the International Catalogue of Arboviruses (Berge, 1975). Approximately one-quarter (77) of these are believed to be tick-borne and a quarter (18) of these have been recovered from man "in nature." In North America, there are 26 viruses reported from hard (Ixodidae) and/or soft (Argasidae) ticks; only two of these have been associated with human illness: Powassan encephalitis—a rare, but sometimes fatal, infection—and Colorado tick fever—the most commonly reported arboviral infection of man in the United States. A third disease entity—Lyme Arthritis—will also be included here although it has not been demonstrated to have a viral etiology or a tick vector; circumstantial evidence suggests that it is an arbovirus.

Powassan is a group B togavirus in the tick-borne encephalitis complex. It was first isolated from the brain of a five year old boy who died of encephalitis in Powassan, Ontario in September 1958 (McLean and Donohue, 1959). Since that time, there have been six additional cases reported in the literature. All seven cases were associated with encephalitis or meningoencephalitis although only two were fatal. Serosurveys indicate that inapparent infections do occasionally occur.

Virus isolations from ticks and rodents and antibody in man and wildlife indicate that the virus is widespread across Canada (Quebec, Ontario, British Columbia) and northern United States (Massachusetts, Connecticut, New York, Pennsylvania, South Dakota, Colorado, California). Recent reports of isolations from *Haemaphysalis longicornis* in the Soviet Union suggest a holarctic distribution (Lvov, et al., 1974).

Serosurveys of wildlife in Canada and the United States implicate mammals, particularly rodents and carnivores, as the vertebrate reservoirs. Virus isolations from woodchucks (*Marmota*), red squirrels (*Tamiasciurus*), skunks (*Mephitis*, *Spilogale*), fox (*Urocyon*), and a mouse (*Peromyscus*)

and from mammal ticks (*Ixodes cookei*, *I. marxi*, *I. spinipalpus*, and *Dermacentor andersoni*) (see Berge, 1975) tend to confirm this. These findings have led workers to the conclusion that several enzootic cycles occur in nature: 1) arborial squirrels and *I. marxi* in the East, 2) medium-sized rodents and carnivores and *I. cookei* in the East and Midwest, and 3) small and medium-sized mammals and *I. spinipalpus* in the Northwest. The role of small rodents with high fecundity rates and short life spans and other species of ticks (e.g. *I. angustus*, *I. scaplaris*, *I. muris*) needs further study.

Transstadial, but not transovarial, passage has been demonstrated in experimentally-infected *D. andersoni* (Chernesky and McLean, 1969). Milk-borne transmission has been detected in experimentally infected goats (Woodall and Roz, 1977).

Colorado tick fever will only be mentioned briefly because it occurs outside the geographic range under discussion here. Early reports of virus isolations from *D. variabilis* on Long Island, New York, appear to have been in error. The distribution of this virus coincides with that of its principal vector, *D. andersoni*, although a serologically related virus, Eyack, was recently reported from West Germany (Rehse-Kuepper, et al., 1976).

Lyme arthritis was first recognized as a disease entity in November 1975, when 51 cases, with onsets dating back to 1967, were observed in three contiguous towns in southern Connecticut (Steere, et al., 1977a, 1977b). Additional cases have since been discovered in Massachusetts, Rhode Island, Connecticut, and New York. Typically, the disease involves an unusual expanding skin lesion—*erythema chronicum migrans*—followed by recurrent episodes of mono- or oligoarticular arthritis; occasionally neurologic or myocardial conduction abnormalities develop. To date, all attempts to detect an etiologic agent by isolation, serology, or electron and light microscopy have failed; however, clinical and laboratory findings suggest a viral immune-complex disease.

The possibility of an arthropod vector was considered for the following reasons: 1) the geographic, seasonal, and familial clustering; 2) the lack of other common sources such as food, water, schools, immunizations, and swimming areas; 3) the association between *erythema chronicum migrans* and *Ixodes ricinus*; and 4) four patients recall a tick at the site of the lesion. An entomological survey in 1976 and 1977 revealed no outstanding differences in the numbers and varieties of Culcidae, Tabanidae, Simuliidae, Ceratopogonidae, Rhagionidae (*Symphoromyia*), or Phlebotominae when compared with collections outside the epidemic area. However, when ectoparasites were examined, a significant difference was noted in the populations and distribution of *I. scapularis* on small rodents, deer, pets, and man.

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EPIZOOTIOLOGY OF ROCKY MOUNTAIN SPOTTED FEVER

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Rocky Mountain spotted fever is an acute febrile disease of nationwide importance. The incidence of this disease, contrary to many predictions, has increased more than four fold in the past two decades. The great majority of cases (approximately 90%) now occur in the eastern United States. A bimodal seasonal incidence pattern has been reported (Hattwick, et al., 1976), with weekly peaks in May and July. In most southeastern states, the highest weekly number of cases occurred in July. In most states west of the Mississippi River and in the northern states, such as Ohio, peak incidence occurred in late May; there was no second surge of cases (Hattwick, et al., 1976). The geographic case distribution pattern has also undergone significant changes in recent years. The most rapid rate of increase in reported cases has occurred in the mid Atlantic region, particularly eastern Pennsylvania and New York (Long Island). This region, which had been reporting less than 5% of eastern United States cases prior to 1970, reported 10% of these cases in 1975. Other areas of unusually rapid increase are in the southern central states, particularly Tennessee, Oklahoma, and Texas. The great increase in reported cases in the latter two states implicates the lone star tick, *Amblyomma americanum* (L.), as the major vector, since that tick is believed to be the most abundant man-biting tick in those states. Nevertheless, the south Atlantic states continue to report approximately 50% of all United States cases.

The distribution of Rocky Mountain spotted fever cases throughout most of the eastern United States corresponds closely with the distribution of the American dog tick, *Dermacentor variabilis* (Say) and this tick is believed to be the dominant vector to man (Sonenshine, et al., 1972). In the southeastern states, overwintering ticks commence activity in early spring (spring cohort); however, the great majority of the man-biting adults emerge in late spring and summer (summer cohort). Thus, the period of greatest risk is in early summer. Most cases occur in rural and suburban communities where the natural vegetation is dominated by forest communities trending towards the oak-hickory-pine climax type. In the northeastern states, the spring cohort constitute the dominant component of the host seeking adults (McEnroe, 1974). The second surge of adults (summer cohort) is smaller, and may not occur at all in some cases. Consequently, the period of greatest risk may be the late sping. Most cases occur in rural and suburan environments where the natural vegetation is dominated by forest com-

munities trending towards the coastal oak-pine climax type. Tick population studies, though very few, suggest that *D. variabilis* may be more abundant in some areas of the south Atlantic states than in parts of the northeastern states. An exception may exist in Nova Scotia, where large populations of *D. variabilis* have been found.

Throughout large areas of the eastern United States, meadow voles, *Microtus pennsylvanicus* (Ord) and white footed mice, *Peromyscus leucopus* Rafinesque) serve as the most important hosts for immature *D. variabilis.* These rodents also serve as amplifiers of the rickettsial infection in nature. Rickettsemic rodents provide a common blood pool for transfer of pathogens from infected to uninfected ticks, concentrating the rickettsiae with each successful engorging life stage. Subsequently, adult ticks feed on a variety of medium and even large mammalian hosts, disseminating the disease more widely among animals and man. Ecological studies have demonstrated that the most favorable natural vegetative association for support of large tick populations is the ecotone between old fields and forests, especially young second growth stands. Temporary clearings, logging roads, trails and other openings that expose the vegetation to intense solar radiation may also provide favorable conditions for ticks. Certain land use patterns prevalent in recent decades may have expanded the available amount of favorable tick habitat. Much land previously cultivated for crops or pasture has been abandoned or is used for frequent timber harvests, suburban development, recreational use or other land management practices that may foster the conditions described above.

Bioclimatological information, though extremely limited, may contribute to an understanding of the distribution of Rocky Mountain spotted fever. The northern distribution of *D. variabilis* appears to be limited by winter temperatures, approximately the January mean temperature, 30°F. In the southern regions of the United States, high summer temperatures may be a factor influencing the distribution of the disease. Few cases occurred in areas with July mean temperatures above 80°F, even though dog tick and lone star tick populations are established in these warmer regions.

Further studies comparing vector tick populations, incidence of *Rickettsia rickettsii* in ticks, and environmental influences may be useful in predicting the future course of the disease.

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EPIZOOTIOLOGY OF HUMAN BABESIOSIS

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Although babesiosis is the first disease of vertebrates proven to be transmitted by blood-feeding vectors (Smith and Kilbourne, 1893), only recently has this tick-borne infection become recognized as a cause of pathology in apparently normal human beings. Since 1958, at least 5 splenectomized persons have become ill due to infection with *Babesia* parasites, mostly of bovine origin (cited in Anderson et al., 1974; Gorenflot et al., 1976). Although sporadic asymptomatic infections have been reported (Healy et al., 1976a; Osorno et al., 1976; Leeflang et al., 1976), frank disease in spleen-intact persons seems limited to islands near Cape Cod, Massachusetts. We know of 17 such cases, 15 occurring within the last two years and 12 occurring on Nantucket Island. *Babesia microti*, a cosmopolitan parasite of small rodents, is the etiologic agent for this unique cluster of human infections (Healy et al., 1976b). Accordingly, we studied the epizootology of babesiosis on Nantucket and nearby islands.

In identifying local reservior hosts for *B. microti*, relatively few candidates need be considered because the mammalian fauna of Nantucket is limited. The white-footed mouse (*Peromyscus leucopus*) and the meadow vole (*Microtus pennsylvanicus*) are abundant as are cottontail rabbits (*Sylvilagus floridanus*) and the white-tailed deer (*Odocoileus virginianus*). Aside from introduced feral rodents and carnivores, few other mammals are common. Rate of infection was measured by inoculating heart blood removed from wild-caught animals. More than three quarters of hamsters became parasitemic after being inoculated with blood from white-footed mice taken from enzootic areas on Nantucket. A lesser proportion of voles carry the infection. Infection in rabbits is rare and the parasite is apparently absent in deer.

In order to compare intensity of parasitemia in potential reservoir hosts, direct smears were prepared from the blood of wild-caught animals. This method for recognizing infection was much less effective than was inoculation of hamsters, revealing less than a third of infections demonstrable by inoculating hamsters. Only once, in a juvenile vole, was the parasitemia intense. Prevalence in mice as measured by direct smear varied with season, reaching maximum levels during mid-summer.

Geographical distribution of infected mice was measured by inoculating hamsters. In general, *Babesia* infection was evident solely in coastal regions where deer were abundant. Thus, various islands appeared to be free of infection as were certain locations on Cape Cod and the mainland.

Relatively few species of ticks are present on Nantucket Island and only two were discovered on white-footed mice: *Dermacentor variabilis* and *Ixodes scapularis*. *I. scapularis* predominates on the mice while *D. variabilis* is more common on voles. Only immature ticks were found on the animals. These findings led to a laboratory study of transstadial passage of the infection in immature *I. scapularis* (Spielman, 1976) and this work established that nymphs of this tick are efficient vectors. *D. variabilis* seemed not to transmit the infection. Nymphal *I. scapularis*, derived from the field, transmitted *B. microti* to laboratory hamsters.

Although immature *I. scapularis* feed most commonly on white-footed mice and adults are most abundant on deer, host range is broad. Larvae and nymphs were abundant on deer and were found on voles, cottontail rabbits, rats, shrews, birds and were surprisingly common on man. Adults were common pests of dogs, cats and man.

The life cycle of *I. scapularis* appears to span 2–3 years on Nantucket Island. Larvae feed from April through September and are most abundant during July. Nymphs attach to mice from March through August with peak-feeding during May and June. Adults seek hosts during early spring and late fall. Thus, larvae feeding during one year produce nymphs which feed the following spring. These, in turn, molt to adults which feed that fall or the following spring. In this manner, the spring brood of susceptible mice are available to potentially infectious nymphs.

Ixodes scapularis, collected during this study, differ from those reported in the southeastern U.S. Morphologically, Massachusetts ticks are similar to those collected in Ontario, Wisconsin, New Jersey, Long Island, Connecticut and Rhode Island. Southern ticks range from Florida north to Virginia and west to Oklahoma and differ in that larvae and nymphs feed most commonly on reptiles (Rogers, 1953) instead of mammals. They rarely attach to man. We will propose, elsewhere, that these northern ticks be designated as a separate species.

It is curious that *I.* sp. nr. *scapularis* was not reported from Nantucket or Martha's Vineyard in the course of tick surveys performed there during the 1930's and 1940's (Hertig and Smiley, 1937; Smith, 1941) while being present on the nearby island of Naushon (Larousse, 1928; Smith, 1943). This may be explained by the scarcity of deer on Nantucket and Martha's Vineyard during this period. These mammals have since become abundant there. Before *I.* sp. nr. *scapularis* became abundant, *I. muris* was a common parasite of small rodents, but this species is now rare. Since *B. microti* was reported on Martha's Vineyard in 1938 (Tyzzer), *I. muris* may have served as an enzootic vector before *I.* sp. nr. *scapularis* became abundant. The wider host range of the latter species would increase risk of human infection.

Several characteristics of the present Nantucket environment appear to favor transmission of *B. microti* to man: (1) Deer are abundant. (2) People have increasing contact with the brush cover presently extending

throughout the island. (3) The mild oceanic climate favors large populations of ticks. In this environment, man's activities lead to intimate contact with large populations of infectious, nymphal, non host-specific ticks.

Acknowledgments

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EPIZOOTIOLOGY OF BOVINE BABESIOSIS AND THE CURRENT STATUS OF *BOOPHILUS* ERADICATION IN TEXAS

J. L. Hourrigan

General

Babsesiosis (piroplasmosis, tick fever, Texas fever, and redwater) is a tick-borne, febrile disease of domestic and wild animals caused by protozoan parasites of the genus *Babesia*. The parasite enters, multiplies within, and causes extensive destruction of red blood cells resulting in anemia, icterus, hemoglobinuria, and death of the host.

The bovine piroplasmosis eradication program was based on elimination of *Boophilus* ticks as the only vector of the disease in the United States. Once the tick vector was eliminated, young cattle were no longer exposed and, therefore, did not develop acute disease or the chronic carrier state. It was thus unnecessary in this country to depend upon premunition or vaccination, drugs, or serological or other testing procedures.

It was found that *Babesia* spp. were transmitted through the eggs, and the tick larvae were infected; that *Boophilus annulatus* and *B. microplus* were one-host ticks, and for practical purposes had a rather limited host range (cattle, horses and mules, deer and, at least under some circumstances, sheep and goats); and that the vector ticks spend a minimum of 19–21 days on the host and could live off the host only a few months, depending upon environmental factors.

Once these facts were established, the parameters for a tick (and piroplasmosis) eradication program could be laid down. Pastures could be left vacant until all larval ticks died, or host animals could be used to "gather the ticks" and regularly dipped at intervals not exceeding the parasitic period of the tick and over a sufficient period that there were no larvae left to be gathered.

Although the principles of eradication were rather simple, the essential rules had to be rigidly followed, and putting together a successful eradication program required considerable money, manpower, effective dips, cooperation, understanding, and hard work. The technical basis for the program has changed little, except for the permitted pesticide being used.

Early Program Problems and Progress in the United States

Cattle fever ticks (*Boophilus annulatus* and *B. microplus*) and bovine piroplasmosis (*B. bigemina* and *B. argentina*) were endemic in our Southern States more than two centuries ago. Losses from the condition were estimated at $40–$100 million per year when the all-out tick eradication program began in 1906.

Eradication progressed slowly, moving from north to south until reaching central portions of Florida in 1933. It was determined that deer were serving as hosts of *B. microplus* to the extent that their numbers had to be greatly reduced in order to permit successful tick eradication.

The *B. microplus* eradication program on Puerto Rico was successfully completed. Cattle, horses, sheep, and goats were dipped during the systematic program. A small number of deer were eliminated.

Efforts to eradicate *B. microplus* from the U.S. Virgin Islands were not successful. Although the ticks were eliminated by systematic dipping from the islands of St. Thomas and St. John, efforts on St. Croix failed. Deer were believed to be perpetuating the infestation. The Pacific island of Guam is also infested.

Situation Following Eradication

In December 1943, *B. annulatus* and *B. microplus* were considered eradicated from the continental United States, except for a narrow buffer zone in Texas extending 500 miles along the Rio Grande River. Although reinfestations by *Boophilus* spp. carried by animals illegally entering the United States occur regularly, clinical disease rarely results. The buffer area, under Federal and State quarantines, is patrolled to reduce and apprehend the animals moving illegally and prevent further dissemination of the ticks.

The program from 1906 through 1943 cost a total of $40 million. If the program had not been carried out, it is estimated that the present cost of the ticks and disease would be $500 million per year.

Present Situation

During fiscal year 1976, cattle fever ticks (*Boophilus* spp.) were collected from 51 herds of Texas livestock located within the quarantined area along the Rio Grande River and from 84 Texas herds north of this quarantined area. In addition, 149 cattle (41 tick-infested) and 54 horses, smuggled or strayed from Mexico, were apprehended. Forty-four alleged illegal movements and smugglings were reported, with 24 defendants fined by year's end.

Two million cattle and 70,000 horses were inspected for ticks, and 281,000 cattle and 50,000 horses were dipped or sprayed.

During the past decade, livestock production in south Texas has changed considerably, with the cattle population doubling in many areas. This has been due to several factors, including clearing brush and planting improved grasses, more watering tanks, and generally increased rainfall. This has greatly favored survival and spread of ticks.

Additional emphasis was placed on the role of wildlife, particularly

whitetailed deer (*Odocoileus virginianus*). Research clearly showed (Florida, 1933) that either *B. annulatus* or *B. microplus* could complete the life cycle on deer. This was further affirmed with *B. microplus* on St. Croix, U.S. Virgin Islands (1962 and 1966) and with *B. annulatus* near Laredo, Texas (1970).

Until recently, there was little reason to believe deer played any significant role in tick eradication in Texas or to consider them in the program. However, there has been a tremendous increase in deer populations, and surveys now underway are revealing that deer may well require more consideration.

Permitted Dips

Under USDA regulations, certain livestock must be dipped in a Department permitted dip prior to their being permitted interstate movement or importation. In addition to having been properly registered and labelled by the Environmental Protection Agency, which includes safety, efficacy, and other requirements, the Food and Drug Administration has certain requirements, including those for tolerances of the pesticide in tissues of dipped animals. Permitted pesticides must meet additional Veterinary Services requirements.

Beaumont crude petroleum was used as an official dip almost exclusively from 1903 until 1910, when the standard arsenical solution was officially recognized. Use of arsenic dip was recently discontinued.

In October 1960, Delnav® was added to the Department's list of permitted dips. In December 1968, coumaphos (Co-Ral®) was added. The most recent addition was toxaphene in July 1972.

No delay between dipping and slaughter is required following use of Delnav® or Co-Ral®.

Dipping certificates are issued to advise interested persons as to the pesticide and concentration used.

Dipping Vat Management

Although the literature includes many papers on the effectiveness of pesticides, it contains comparatively little on formulation or dips and the proper procedure of actually applying the pesticide to the animal. Programs can easily fail because of this.

Acaricide Resistance

Although we have been dipping cattle because of *Boophilus* spp. ticks in the United States for some 85 years, we have never recognized acaricide resistance as being a problem. We attributed the lack of a problem to

our steadfast desire to eradicate, not to control, ticks. We used the highest practical concentration of arsenic, not the lowest.

We realize that acaricide resistance is a real and serious problem in many areas of the world.

It is encouraging to know that the Foreign Agriculture Organization is well along in developing a standard test kit to detect acaricide resistance in tick populations.

Research Activities in the United States

Research in the United States for cattle fever ticks has been recently revived. The U.S. Livestock Insects Laboratory (ARS-USDA) at Kerrville, Texas, has established a sublaboratory (Cattle Fever Tick Research Laboratory) at a 30-acre site on a peninsula just below Falcon Dam on the Rio Grande River near Falcon, Texas.

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FORAGING BEHAVIOR IN THE HYMENOPTERA

Robert F. Denno—Organizer and Moderator

(Summaries of papers presented at the Forty-ninth Annual Meeting, Eastern Branch, Entomological Society of America, Boston MA, 14 September 1977).

Opening Comment

One of the currently burgeoning areas of ecology concerns the mechanisms by which organisms obtain requisites and the associated costs and benefits of obtaining these resources. Resources occur in a variety of configurations in the environment. They may be dispersed or concentrated, ephemeral or permanent, large or small, and vary in nutrient quality. Together, this constellation of states characterizes a particular resource, presents an ecological trade-off between the energy gained from the resource and the energy constraints of exploitation, and ultimately dictates the optimum foraging strategy of organisms.

In addition to the effects of the resource itself, the foraging pattern of a species may be modified by the physical environment, competitors, predators, and the like. Clearly, foraging is a complex behavior affected by a multitude of factors.

Certain approaches to understanding foraging organisms have emphasized coevolutionary interactions, some center on the energetics of foraging, and others on the niche-relationships of the species involved. Historically, a more empirical or observational tack has been taken. Recent investigations, however, including some of those that follow, have employed an experimental approach.

Major contributors to foraging strategies have come from the study of several groups of Hymenoptera; bees and ants in particular. Apparently, because of their size, density, and the usual ease by which the resources they exploit can be measured, the Hymenoptera are rather ideal experimental animals.

In this symposium we explore some of the factors which dictate foraging patterns of species, provide evidence by both empirical and experimental means, and further elucidate the unique value of Hymenoptera as study organisms.

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FORAGING PATTERNS AND PLANT SELECTION IN COSTA RICAN LEAF CUTTING ANTS

Larry L. Rockwood

Introduction

Leaf-cutters are new world Myrmicine ants of the tribe Attini, the fungus growers. Species of the genus *Atta* can be found throughout the tropics and subtropics from Texas and Louisiana to Argentina (Weber, 1972). In spite of their importance to neotropical ecosystems and their status as important pests of agriculture (Haines, 1978), our understanding of *Atta* foraging has been limited. Here I discuss several aspects of foraging by *Atta colombica* Guer. and by *Atta cephalotes* L. in the Guanacaste Province of Costa Rica. The bulk of the data are based on an intensive year-long study of three colonies of each species conducted in 1970–71. The results have been described in a number of publications (Rockwood, 1972, 1973, 1975, 1976; Rockwood and Glander, 1978). Other data derive from short term studies conducted in 1973 and 1975 with S. P. Hubbell (Hubbell and Rockwood, 1977). I will concentrate here on the effects of plant selection, resource abundance, and resource distribution on foraging in these two species of *Atta*.

Leaf-cutting ants forage by moving along the ground in well-defined trails, clearing debris until a smooth path is worn in the forest floor. The trails usually lead up the stem of the plant being attacked, though general foraging at the base of a plant for flowers or dropped leaves is common in certain situations, and leaves, flowers, or fruit are cut. The material is carried back to the nest where it is placed in a fungus garden. The fungus serves as the only food for the larvae and most probably for the adult ants. Colonies of *A. colombica* and *A. cephalotes* are territorial (Rockwood, 1973) and long-lived. Queens have been known to live as long as 25 years in the laboratory. See Weber (1966, 1972) for other details of the life history.

Seasonal patterns in foraging by *A. colombica* and *A. cephalotes* have been described elsewhere (Rockwood, 1972, 1975). These patterns include the following: 1) the amount of material harvested by the ants shows great seasonal variation, with relative peaks at the beginning of the wet and dry seasons, and lows during the middle or end of these seasons. These peaks in foraging are related to the number of plant species producing new leaves or flowers. 2) The type of material cut also changes with season. Colonies harvest new leaves at the beginning of the wet and dry seasons and flower parts during the dry season. It has been my hypothesis

Table 1. Classification of the plant species present in the foraging areas of colonies of *A. colombica* based on Rockwood (1972). Classifications are: (A) Mature leaves readily acceptable, (B) Mature leaves apparently unacceptable, (C) New leaves only acceptable. The number of observed laden ants must exceed 1% of the grand total of observed laden ants for any one colony for a plant species to be considered acceptable.

	Mean number of observed laden ants per plant species			Number of plant species
	Colony 1	Colony 2	Colony 3	
Category A	771	623	406	27
Category B	47	15	18	43
Significance	$P < .001$	$P < .001$	$P < .001$	
Category C				
New leaves	671	262	193	16
Mature leaves	34	5	10	
Significance	$P < .003$	$P < .003$	$P < .113$	

that, since many mature leaves contain unpalatable compounds that are potentially toxic to the fungus and/or slow the fungal growth rate, the preference for young leaves or flowers is due to the fact that these plant materials contain smaller amounts of toxic compounds and are higher in available nutrients and proteins (Feeny, 1970, 1976).

Leaf-cutters can best be understood as generalist herbivores with an apparently fixed resource base, but whose resources are actually changing constantly in terms of their relative suitability as substrate for the fungus gardens. Since colonies are relatively long-lived, a successful colony will be one which harvests enough energy from the vegetation to produce ample reproductives, but which does not damage its resource plants enough to endanger the future food supply. In other words, the ants should harvest the "interest" from the system without endangering the "capital."

Selectivity

Colonies of *A. colombica* and *A. cephalotes* in Guanacaste are generalist herbivores, yet are extremely selective. Of the six colonies studied, the most active *A. colombica* and *A. cephalotes* colonies sampled leaves from 77% and 67% of the woody plant species recorded from the foraging areas, respectively. The other four colonies sampled leaves from 49–60% of the woody species within their territory (Rockwood, 1976). Yet while engaging in an extensive sampling program, colonies of *Atta* were extremely selective and concentrated their foraging efforts on a much smaller subset of plant species. Such favorite plant species as *Cassia biflora*, *Enterolobium*

Table 2. Classification of plant species present in the foraging areas of colonies of *A. cephalotes* based on Rockwood (1972). Classifications are the same as those in Table 1.

	Mean number of observed laden ants per plant species			Number of plant species
	Colony 41	Colony 43	Colony 48	
Category A	516	279	667	13
Category B	5	17	8	34
Significance	$P < .089$	$P < .001$	$P < .001$	
Category C				
New leaves	180	703	172	12
Mature leaves	3	6	1	
Significance	$P < .223$	$P < .007$	$P < .077$	

cyclocarpum, and *Quercus oleoides* were being attacked by the ants on as many as 33 of 44 (75%) observations throughout the year and cut at high rates, while the majority of plant species were visited three times or fewer and cut at very low rates (Rockwood, 1976). By one analysis (Tables 1 and 2), *A. colombica* concentrated its foraging for mature leaves on 27

Table 3. A statistical analysis, using the Hypergeometric distribution, of the probability that each colony of *Atta colombica* is selecting leaves without regard to the identity of the plant species. Colonies are compared pairwise and simultaneously.

Number of plant species available in the foraging area of both colonies being compared	Number of preferred plant species available in the foraging area of both colonies[1]			Number of plant species preferred by both colonies	Probability of x species being preferred by both colonies[2]
	Colony 1	Colony 2	Colony 3		
N	n_1	n_2	n_3	x	$p(x)$
47	8	11	–	4	$P < 0.003$
40	6	–	7	4	$P < 0.005$
43	–	10	8	4	$P < 0.002$
All three colonies					
37	6	9	7	3	

[1] The number of laden ants observed must exceed 2.5% of the grand total for that particular colony in order to be considered preferred by that colony, i.e. greater than 662 (.025 × 26478 for colony 1, greater than 408 (.025 × 16352) for colony 2, and greater than 276 (.025 × 11028) for colony 3 (Rockwood, 1972).

[2] $p(x) = \binom{n_j}{x}\binom{N-n_j}{n_i-x}/\binom{N}{n_i}$.

Table 4. A statistical analysis, using the Hypergeometric distribution, of the probability that each colony of *Atta cephalotes* is selecting leaves without regard to the identity of the plant species. Colonies are compared pairwise and simultaneously.

Number of plant species available in the foraging area of both colonies being compared	Number of preferred plant species available in the foraging area of both colonies[1]			Number of plant species preferred by both colonies	Probability of x species being preferred by both colonies[2]
	Colony 41	Colony 43	Colony 48		
N	n_1	n_2	n_3	x	$p(x)$
26	4	8	–	3	$P < 0.067$
27	4	–	5	3	$P < 0.013$
31	–	9	6	5	$P < 0.004$
All three colonies					
24	4	7	5	3	

[1] The number of laden ants observed must exceed 2.5% of the grand total for the particular colony in order to be considered preferred by that colony, i.e. greater than 154 (.025 × 6208) for colony 41, greater than 249 (.025 × 9965) for colony 43, and greater than 198 (.025 × 7932) for colony 48 (Rockwood, 1972).

[2] $p(x) = \binom{n_j}{x}\binom{N-n_j}{n_i-x}/\binom{N}{n_i}$.

of 86 (31.4%) possible plant species while *A. cephalotes* used mainly 13 of 59 (22.0%) possible plant species as sources for mature leaves. In both cases the new leaves of some plant species were acceptable for cutting.

Two other lines of evidence point to a consistent selectivity in *Atta*. One analysis, first presented in Rockwood (1976), shows that there exists an inter-colony consistency in terms of which plant species are most preferred (Tables 3 and 4). In this analysis a preferred species was defined as a species for which the number of observed laden ants exceeded 2.5% of the colony-specific grand total of laden ants from all plant species for the observation year. Each colony's list of preferred plant species was independent of those of the other colonies. Colonies were compared pairwise. For *A. colombica* each pair of colonies had four species in common on their preferred lists and three plant species made the preferred list of all colonies (*Cassia biflora*, *Cordia colococca*, and *Eugenia salamensis*). The probability, $p(x)$, that these x common species were selected by chance was significantly low in all cases ($P < 0.005$). For *A. cephalotes* two comparisons were highly significant and one was marginally significant ($P < 0.075$). Three species were preferred by all colonies (*Enterolobium cyclocarpum*, *Lygodium polymorphum*, and *Quercus oleoides*).

A second line of evidence which confirms the consistency of plant selection among colonies, is a rank correlation analysis (Table 5). In this analysis,

Table 5. Kendall coefficients of rank correlation based on plant species preferences between pairs of *A. colombica* and *A. cephalotes* colonies.

Colonies compared for plant preferences	Coefficient of rank correlation	Probability that rank correlation arose by chance
A. colombica		
1 and 2	0.186	0.091
1 and 3	0.308	0.013
2 and 3	0.256	0.039
A. cephalotes		
41 and 43	0.423	0.003
41 and 48	0.403	0.003
43 and 48	0.290	0.022

plant species are ranked for each colony according to yearly totals of leaf-cutting per plant combined by species. Fruit, flower and leaf-cutting are combined. Colonies are compared pairwise and a Kendall coefficient of rank correlation, τ, computed for each comparison (Sokal and Rohlf, 1969). Only plant species present in both foraging areas being compared are used in the analysis. For colonies of *A. colombica* the correlations range from a low of 0.186 to a high of 0.308. The best two correlations are significant at the 5% level but the correlation between colonies 1 and 2 is only marginally significant. This probably is caused by the fact that colony 2 foraged largely in second growth while colony 1 foraged in a riparian forest. The *A. cephalotes* colonies, which foraged in the more uniform *Quercus oleoides* forest, show very high correlations. Two of these correlations are above 0.40 and all are significant at the 5% level.

Resource Abundance

Another important question regarding leaf-cutter foraging is, what is the relationship between plant species abundance and leaf-cutter foraging? This is a complex question. As has been shown before (Rockwood, 1976), some of the most frequently attacked plant species are those which are rarest, while common plants are virtually ignored by the ants (Table 6). In four of the six colonies studied there was no correlation between the number of trees of a species and the amount of ants observed carrying leaf parts from that species. This was due mainly to the large amounts cut from such favorite but relatively rare species as *Bombacopsis quinata*, *Mastichodendron tempisque*, and *Enterolobium cyclocarpum*. Nevertheless, where foraging is not dominated by these rare species, as in colonies 2 and 43, there exist high positive correlations, significantly different from zero.

Table 6. Correlation between the number of trees over 40 cm DBH (Diameter Breast Height) of a species and the total number of laden ants observed carrying leaf parts from that species.

Colony	Linear correlation coefficient	Sample size
A. colombica		
Colony 1	–0.181	53
Colony 2	0.6021[a]	43
Colony 3	0.1101	39
A. cephalotes		
Colony 41	0.1220	24
Colony 43	0.5477[a]	24
Colony 48	–0.0335	31

[a] Correlation significantly different from zero ($P < 0.01$).

Data from a more recent study are relevant to this point. Twenty colonies of *A. cephalotes* were studied intensively for a month in the Santa Rosa National Park in Guanacaste in 1973 (Hubbell and Rockwood, 1977). Foraging was examined on at least five different occasions for each colony. If a plant species was visited at least once by one colony, we called it a resource species. We then determined the number of resource trees available in each colony's foraging area. Figures 1 and 2 show the results of this analysis. Figure 1 shows there is a significant ($r = 0.704$, $P < 0.01$) positive relationship between the number of species visited by a colony and the number of resource species available. Note that no colony visited fewer than two different species during the month's study and most visited three or more. Figure 2 indicates that there is also a positive correlation ($r = 0.788$, $P < 0.01$) between the total number of resource trees available and the total number of trees visited. Yet there is no relationship whatsoever between the number of resources available and the actual amount cut by a colony during the study period ($r = -0.032$). There is also no significant relationship between number of resource trees and amount cut. This means that having more resources encourages a colony to switch from one tree to another and even from one plant species to another, but doesn't necessarily mean that more vegetation will be cut by that colony.

Resource Distribution

How do the ants distribute foraging effort over distance? Is there an optimal strategy? Again, this is a complex question. Two possible foraging strategies with regard to distance have been discussed by Hubbell and Rockwood (1977). First, leaf-cutters may minimize the costs of retrieving

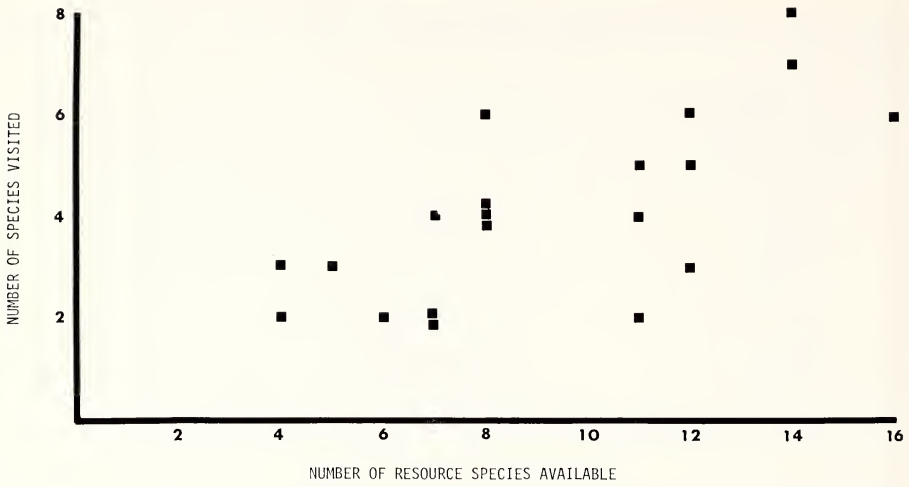

Fig. 1. Number of resource species available to a colony of *A. cephalotes* versus the number of species visited by that colony. Product-moment correlation coefficient, $r = 0.704$, $P < 0.01$.

various food types from different distances, subject to the constraint that each food type must be obtained in some minimal amount to satisfy the nutritional needs of the colony. This means that the ants would cut more individuals of the same species which were closer to the nest and less from those individuals farther away. A second possibility is that the ants do not minimize retrieval costs but maximize benefits gained from foraging on resource species which are best nutritionally or low in toxicity, subject to the constraint that foraging is spread more or less evenly throughout the territory. Hubbell and Rockwood (1977) found that this second model fit the data better than the first model for most of the 20 colonies studied. But the data are for a very short period of time and the models deal only with number of trees visited, not with amount cut from each tree visited.

Any argument involving foraging by distance is again complicated by selectivity, the dominant factor in *Atta* foraging. In Figures 3 and 4 yearly mean proportions of observed foraging in 5 m distance categories are plotted against distance for three colonies of *A. colombica* and *A. cephalotes*. Depending on the colony, relative peaks appear unpredicatably anywhere within the first 60–80 m from the nest. These sudden peaks in foraging at certain distances are generally due to favorite host plants at that distance. In colony 3 the unusual amount of foraging in the 110–120 m interval is due to a single *Bombacopsis* tree and a group of five *Mangifera indica* trees. The high points in colonies 41 and 48 are accounted for by the presence of single *Enterolobium* trees.

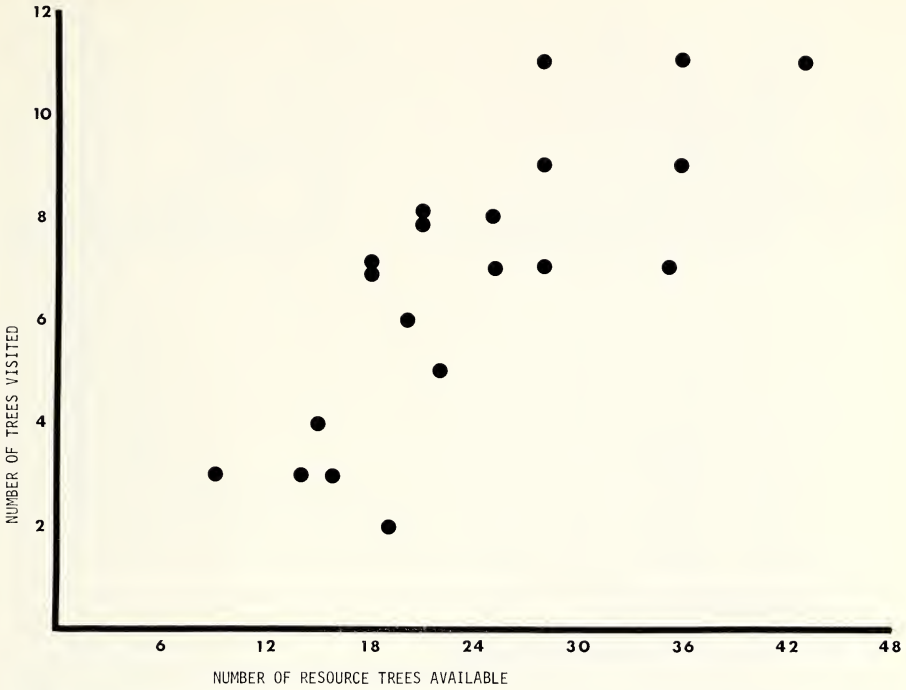

Fig. 2. Number of resource trees available to a colony of *A. cephalotes* versus the number of trees visited by that colony. $r = 0.788$, $P < 0.01$.

If the data on distance from all three *A. cephalotes* colonies are combined, some of the effects of the unique distribution of resource trees around each colony cancel out, and it is possible to perceive several patterns (Table 7). First, the absolute number of trees visited increases to about 30 m and then declines with distance. This is partially an artifact of the increased area and therefore number of available trees per 10 m distance category. The percentage of resource trees visited is highest in the first distance category (0–10 m) and declines in a regular fashion with distance. So trees closest to the nest have greater chances of being visited by the ants at least once a year than do trees farther away if one ignores species. Nevertheless, resource trees within 60 m of the nest had a 20% chance or greater of being visited during the observation year. The amount cut from each distance category, however, shows no such regular pattern. More leaf fragments were observed being cut from the 40–49 m category than any other. When the number of laden ants is divided by the available trees, however, the two closest categories yield the highest ratios, though other distance categories are still important.

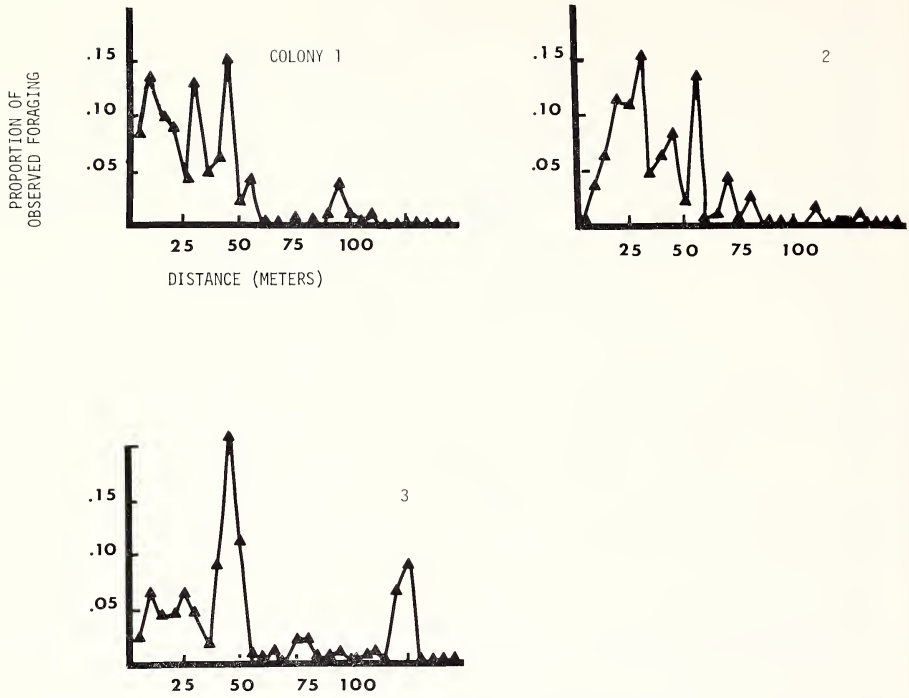

Fig. 3. Yearly mean proportion of observed foraging in 5 m distance categories in colonies of *A. colombica.*

In a previous publication (Rockwood 1976), I analyzed foraging by distance for specific, common, tree species regularly attacked by the ants. In all cases the trees within ten meters of the nest had a very high chance of being visited (75% or greater), but there was great variability at other distances. In terms of amounts cut and leaf-cutting/available tree, there was similar variation. By combining these data (Table 8) some of this variation cancels out and a number of patterns, similar to those above, become evident. Again, the absolute number of trees visited increases with distance to 20–40 m, but the perecntage of trees visited declines with distance. The number of observed laden ants is highest for the 0–9 m and the 30–39 m intervals. But leaf-cutting per available tree shows a strong relationship to distance. The number of observed laden ants/available tree for the first interval (0–9 m) is almost twice that of the second interval (10–19 m) and four times that of the third distance category (20–29). Beyond 30 m the amount falls off more gradually.

These data contradict the findings of Hubbell and Rockwood (1977) which predict that foraging should be spread more or less evenly throughout the

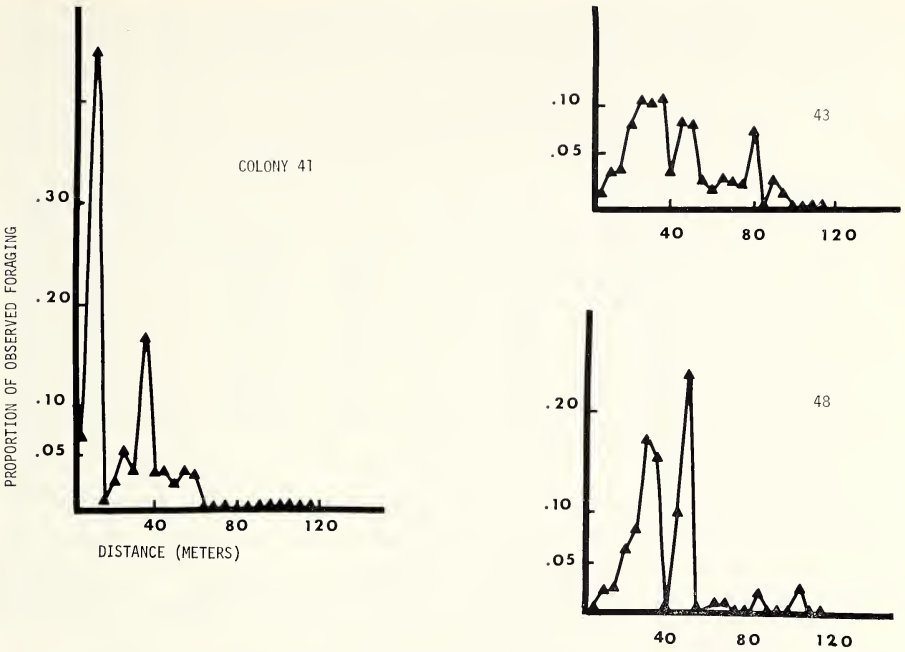

Fig. 4. Yearly mean proportion of observed foraging in 5 m distance categories in colonies of *A. cephalotes*.

territory. But it must be remembered that the tendency to concentrate foraging closer to the nest only reveals itself when data from several resource species or several colonics are combined. As the data from the 20 Santa Rosa colonies of *A. cephalotes* and subsequent analyses indicated (Hubbell and Rockwood, 1977), when given the opportunity colonies of *Atta* will switch from one indivdual plant of a species to another in irregular and unpredictable patterns. Colonies routinely cease foraging on a particular tree only to begin cutting leaves from a tree of the same species further away from the nest. A particularly bizarre example is colony 43 of *A. cephalotes* which cut more leavcs of *Spondias mombin* from 50–59 and 60–69 m distance categories than from any other distances, even though five or more trees were available in each of the nearest distance categories (Rockwood, 1976).

There may be subtle changes in leaf chemistry which would explain some of these patterns. For example, Glander (1977) rcccntly found that six *Gliricidia sepium* trees whose leaves were regularly ingested by howling monkeys (*Alouatta palliata*) lacked defensive compounds (alkaloids) which were present in the 146 individuals whose leaves were not eaten. In addition, Glander (personal communication) has recently found that the new

Table 7. Analysis of foraging by distance combining data from three colonies of *A. cephalotes*. Survey of available trees includes all individuals greater than 40 cm dbh of species which were visited at least once during the observation year and found within 70 m of nest.

Distance from nest (m)	Trees visited/ available	(%)	Observed laden ants (*N*)	(%)	Laden ants/ available tree
0–9	19/30	63.3	4,591	0.211	121.9
10–19	23/48	47.9	2,862	0.131	59.6
20–29	39/96	40.6	4,270	0.196	44.5
30–39	35/114	30.7	2,850	0.131	25.0
40–49	26/93	28.0	5,324	0.245	57.2
50–59	19/81	23.5	1,225	0.056	15.1
60–69	9/64	14.1	651	0.030	10.2

leaves of a variety of Guanacaste trees contain twice as much protein as do mature leaves. Since both howling monkeys and leaf-cutters select new leaves in many plant species, both organisms are likely to be selecting vegetative material which is both high in essential nutrients and low in secondary compounds (Rockwood and Glander, 1978).

More data on the biochemical properties of the leaves and other material harvested by the ants, and their effects on the growth of the fungus gardens are needed before some of the complexities of leaf-cutter foraging are understood.

In conclusion, the primary component of leaf-cutter foraging is selection of the leaves and other material such as flower parts and fruit which will be suitable for growth of the fungus. Maximizing nutrients and minimizing potentially toxic secondary compounds appears to be much

Table 8. Analysis of foraging by distance for specific tree species which were both common and regularly visited by the three *A. cephalotes* colonies. Based on Table 10 of Rockwood (1976).

Distance from nest (m)	Trees visited/ available	(%)	Observed laden ants (*N*)	(%)	Laden ants/ available tree
0–9	14/18	77.8	1,579	21.5	87.7
10–19	13/23	56.5	1,123	15.3	48.8
20–29	24/62	38.7	1,396	19.0	22.5
30–39	24/78	30.8	1,490	20.2	19.1
40–49	12/48	25.0	696	9.5	14.5
50–59	9/64	14.1	650	8.8	10.2
60–69	5/36	13.9	427	5.8	11.9

more important than minimizing retrieval costs by attacking plants closest to the nest. There is some evidence that having more resource species and individuals present leads to more switching and therefore more trees visited. There is no necessary relationship, however, between total amount cut from all species and the number of resources present, at least in the short time span of one month. Over several years, however, this switching behavior could lead to a more even distribution of foraging among individuals, all else being equal. Finally, minimizing retrieval costs may play a minor role in foraging by *Atta*. The factors mentioned above predominate, and it must be emphasized that leaf-cutter foraging is highly irregular and unpredictable, especially in the short term, but there appears to be a tendency for *A. cephalotes* to exploit those trees nearest the nest within a given species. This result is contradicted by the results of Hubbell and Rockwood (1977) which were based on a one month study of 20 colonies. Further research on a large number of colonies over long periods of time are needed to resolve this question.

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POLLINATOR SERVICE IN SYMPATRIC SPECIES OF JEWELWEED (*IMPATIENS*: BALSAMINACEAE)

R. W. Rust

Since the 18th century biologists have been interested in the angiosperm flower as a mechanism for attracting insects and other agents to mediate sexual reproduction (Miller, 1724; Dobbs, 1750; Sprengel, 1793). In many obligate outcrosses seed production is solely dependent upon those insects responsible for proper transfer. If the number of pollinators is insufficient with respect to the number of self-incompatible flowers present, then the flowering species may be competing for limited pollinator services.

The consequences of interspecific competition for pollinator service by the honey bee has been a recognized economic problem for both apple and pear production in the presence of the more attractive white mustard, storkbill, and dandelion (Free, 1968, 1970). The pollinator services of the honey bee on alfalfa flowers are reportedly preempted by field crops of red clover, sweet clover, mustard and sunflowers (Hobbs, 1950; Menke, 1954; Palmer-Jones and Forster, 1965). Competition for pollinators in natural ecosystems has been noted in sympatric and synchronic species in the arctic and north temperate latitudes during the growing season (Hocking, 1968; Mosquin, 1971). Competition for pollinator service has received theoretical attention by several workers who have developed models to predict the outcome of competitive interactions on the basis of pollinator movement, pollinator constancy, flower density, etc. (Levin and Anderson, 1970; Straw, 1972). Yet the prevalence of competition for pollinator service and its relative importance as an organizing influence on interspecific interactions have not been ascertained.

As part of a more general study of plants and their pollinators, I selected to assess the competitive interactions between two species of jewelweed (*Impatiens*) which occur predominantly in separate patches along the flood plain of White Clay Creek in northern Delaware, but which occasionally are found growing together. It was assumed that if competition for pollinators were operating, it would become apparent in a comparison of plant-pollinator interactions between single-species and mixed-species patches. In addition to their microdistributional patterns these two species proved ideally suited to a competitive study for the following reasons: 1. they have similar floral structures and bloom synchronically, 2. they are completely dependent on the activities of pollinators for their reproduction, 3. they share pollinators, 4. they have a deficiency of pollinators relative to the number of flowers present as measured by the lack of 100% seed set.

Table 1. Floral characteristics and phenologies of *Impatiens capensis* and *Impatiens pallida* presented as means and standard deviations and sample size.

Characteristic	*I. capensis*	*I. pallida*
Saccate sepal length (mm)	18.2 ± 1.22 ($n = 35$)	10.4 ± 0.91 ($n = 25$)
Saccate sepal height (mm) (distance below androecium)	4.1 ± 0.43 ($n = 35$)	6.9 ± 0.42 ($n = 25$)
Spur length (mm)	8.6 ± 0.96 ($n = 35$)	5.2 ± 0.48 ($n = 25$)
Flower duration (days)	1.6 ± 0.63 ($n = 38$)	2.5 ± 0.86 ($n = 45$)
Androecium shed (days)	1.4 ± 0.52 ($n = 38$)	2.2 ± 0.84 ($n = 45$)
Nectar production (μl/24 h)	2.8 ± 1.61 ($n = 53$)	2.4 ± 1.56 ($n = 71$)
Nectar sugar (%)	43.1 ± 13.15 ($n = 43$)	41.5 ± 10.78 ($n = 24$)

Flowers

Flowers of the orange-flowered jewelweed (*Impatiens capensis*) and the yellow-flowered jewelweed (*I. pallida*) are single, pendant, perfect, zygomorphic, protandrous, superior and theoretically 5-merous. They have 2 small green upper sepals and an enlarged saccate sepal open in the front and spurred at the bottom. The petals consist of an upper which is broader than long and 2 lobed lateral petals (regarded as 2 united). The saccate sepal and petals are orange in *I. capensis* and yellow in *I. pallida*. In both species, the saccate sepal and petals are spotted in various degrees with red. The saccate sepal in *I. pallida* is shorter and abruptly bent downward as compared to *I. capensis* (Table 1). Flowers of the 2 species exhibit minor differences in UV reflectance-absorbance patterns. In *I. capensis*, both surfaces of the saccate sepal and the inner surface of the petals absorb UV light and the anthers reflect it, while in *I. pallida*, only the lower surfaces of the saccate sepal and the middle section of the 2 lobed petals and the anthers absorb UV light (Rust, 1977).

In both species the 5 stamens form a covering over the stigmatic surface until the androecium is pushed off by the elongation of the ovary, about 4–6 h before the flower drops from the receptacle (Table 1). The androecium protects the flower against self pollination. Nectar is produced in the spur of the saccate sepal and production begins just prior to anthesis. Daily accumulation in the saccate sepal amounted to approximately 2.5 μl per flower and the percent sugar averaged about 42% for both species (Table 1). Nectar amino acids were different in the 2 species. *Impatiens pallida* nectar contained 14 amino acids while *Impatiens capensis* nectar contained 24 amino acids of which 5 were in concentrations greater than 100 nmol/ml. *Impatiens capensis* nectar contained all of the amino acids of *I. pallida* except phosphoserine; *I. capensis* had an average of nearly twice the total amino acids per ml nectar than *I. pallida* (2.1 μmol/ml to 1.1 μmol/ml)

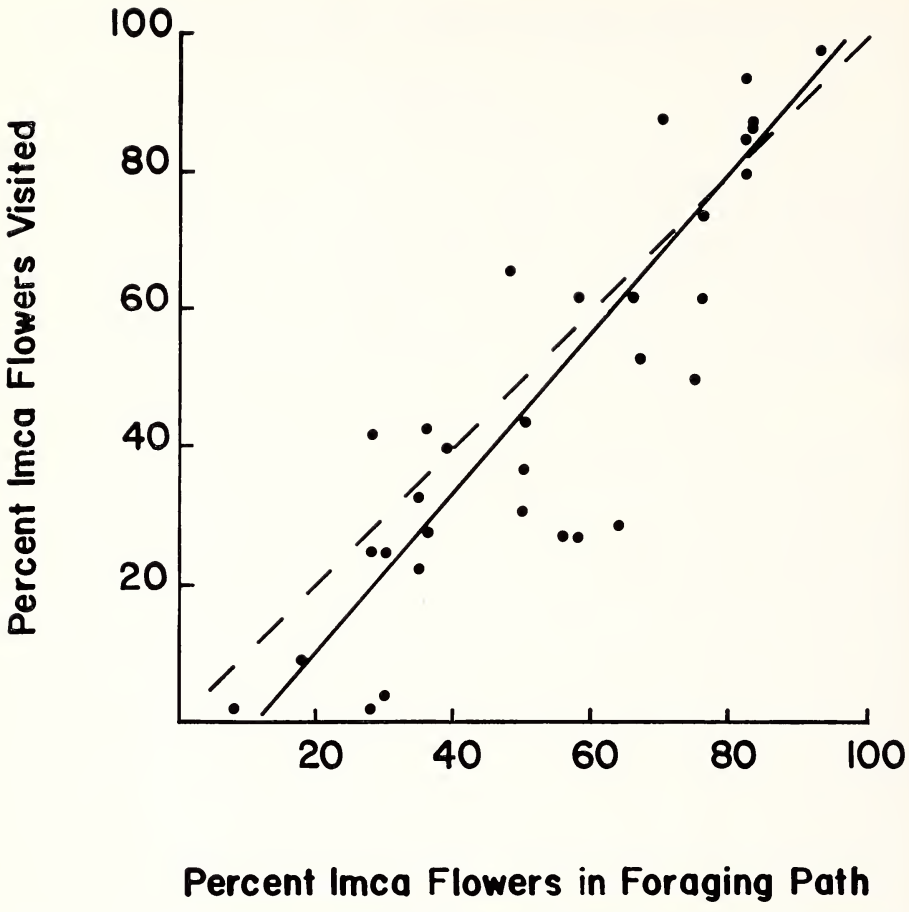

Fig. 1. Visitation pattern of *Bombus vagan* in mixed-species patches of *Impatiens capensis* and *Impatiens pallida* ($Y = 1.210X - 14.497$; $Ho{:}b = 1$, $0.05 < P < 0.10$). The dashed line equals the 1:1 relationship.

(Rust, 1977). However, the significance of different nectar compositions with respect to the attractiveness to pollinators has not been determined.

Pollinators and Flower-Pollinator Interactions

The 2 species shared the same principal pollinators, the bumblebees *Bombus vagans* and *B. impatiens*. Although other species were recorded visiting *Impatiens*, their numbers were relatively few. For this reason I restricted my behavioral observation to *B. vagans* and *B. impatiens*.

In an attempt to unravel the interspecific interactions, if any, as they related to pollinator service and to measure pollinator constancy and visita-

Table 2. Percentage of marked flowers of *Impatiens capensis* and *I. pallida* producing seeds in single- and mixed-species patches.

Date	*Impatiens capensis*		*Impatiens pallida*	
	alone	mixed	alone	mixed
21 August	81.4	87.1	91.6	93.3
28 August	76.7	83.3	75.0	100.0
4 September	65.7	77.7	70.0	84.5
11 September	74.0	83.8	54.5	86.1
18 September	57.1	40.0	75.0	81.8
Mean	70.9	74.3	73.2	89.1

tion rates, I followed an individual bee on a foraging trip through mixed-species and single-species patches recording the flowers visited and the time spent. Then I went back and counted the total number of flowers of each species in the foraging path and used these data to estimate the percentage of flowers of each species visited relative to their respective abundances. If there were no strong preference for or avoidance of either species by the pollinators, then I predicted that visitation should equal occurrence, i.e. the bees would have a low constancy.

Using *I. capensis* percentage of occurrence as the base, there was a significant increase in visitation when regressed against an increase in the percentage of *I. capensis* in a mixed-species patch (Fig. 1). In fact, the slope of the regression approached unity ($b = 1$), the perfect 1:1 relationship shown as the dashed line in Fig. 1. This means that as the percentage of *I. capensis* increased or decreased in a mixed patch, the visitation increased or decreased proportionately. *Bombus vagans* showed no constancy for one *Impatiens* species over the other. Insufficient numbers of *B. impatiens* have been timed to permit analysis. However, they appear to exhibit the same low level of constancy. Thus, the species' floral displays and rewards appear to be equally attractive to the principal pollinators. The bees do not respond to the differences between the *Impatiens* species, but move from flower to flower with a frequency proportional to the occurrence.

A comparison of visitation rates by pollinators was made to determine whether or not the lack of constancy affected these rates and hence the number of flowers pollinated in mixed-species patches. The rate of flowers visited by *Bombus vagans* averaged 8.4 ± 2.3/minute in *I. capensis* patches, 12.7 ± 3.6/minute in *I. pallida* patches, and 10.5 ± 2.5/minute in mixed-species patches. This latter value is intermediate and thus suggests that visitation rates are not significantly affected in mixed-species patches.

The second measurement of competition for pollinators involved marking

flowers and following subsequent seed production. Individual flowers were marked with a 5 cm piece of size 40 cord tied around the pedicel. Approximately 50 flowers per week were marked in both mixed-species patches and single-species patches during each week throughout the flowering period. Marked, hand-pollinated flowers produced 100% seed set. For *I. capensis* there was no difference ($t = 0.461$, $P > 0.50$; based on arcsine transformation of the data) in pollination-seed production between mixed- and single-species patches (Table 2). However, *I. pallida* showed a significantly higher percentage of pollination-seed production in mixed-species patches ($t = 2.306$, $0.05 < P < 0.01$) (Table 2). It appears that *I. pallida* benefits from its association with *I. capensis* in terms of seed set, i.e. *I. pallida* exhibits facilitated pollination service in the presence of *I. capensis*. *I. capensis* neither benefits from nor is harmed by the presence of *I. pallida* with respect to seed production.

Conclusions

The fact that the two species of *Impatiens* were rarely found growing together, though both existed in the same general area, suggested that some form of competitive exclusion was taking place. Having obtained 100% seed set in both species through hand pollination and knowing seed set to be less than 100% in either species under natural conditions, it was concluded that pollinators may be limited and could be exerting a selective pressure on the species to become more "attractive" to the pollinators. However, constancy was not determined by the pollinators for one species of *Impatiens* over the other. There was an equal visitation in relation to the proportion of flowers of both species present. *Impatiens capensis* and *I. pallida* are not competing for pollinator service. Observations indicate that they are most likely competing at the level of seedling growth or perhaps seed survival.

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FORAGING OF BUMBLE BEES: THE EFFECT OF OTHER INDIVIDUALS

Douglass H. Morse

Introduction

Few experimental studies have been published upon the role that direct interactions play in niche partitioning under natural conditions, and even in these cases the mechanisms causing partitioning have seldom been reported (Kikuchi, 1965; Grant, 1970; Colwell and Fuentes, 1975; Morse, 1977). Therefore, I elected to explore this question, using a system which would readily permit me to study the basis for niche-shifting both rigorously and realistically. For this effort I chose a group of bumble bees (*Bombus* spp.: Apidae) that inhabit fields and other open places in the northeastern United States. This is part of a larger study upon foraging behavior and predator avoidance by bumble bees. The bumble bees, as I will demonstrate, provide the necessary criteria for testing both rigorously and realistically the hypothesis that an individual changes its foraging patterns in response to another species, and to investigate the basis for this change. Perhaps even more important, given that the individuals of an area concentrate on localized food sources, it becomes possible to assess the importance of the different species upon each other.

Here I present the results of several field experiments testing the effects of *Bombus ternarius* Say and *B. terricola* Kirby on each others' foraging on goldenrod (*Solidago juncea* and *S. canadensis*). I further compare them with observations made upon individuals, in many cases the same ones, that foraged unrestrained on similar flowers.

Bumble bees typically walk along the branches of these plume-like inflorescences gathering nectar from the florets. Any individual can feed from any of these florets and can also hang from the pendant tips of the branches if these branches will not otherwise support its weight. Most individuals forage for nectar, although they may acquire considerable amounts of pollen at the same time, as is easily witnessed by their characteristic bright orange corbiculae.

Methods

At the start of an experiment I placed a screen-covered cage of about one m^3 over a clump of goldenrod, which had 8–12 stalks with inflorescences. These flowers were left uncovered at all times when experiments were not being run, therefore keeping nectar volumes consistent with those elsewhere in the field. A bee was released into the cage from the bottom. After

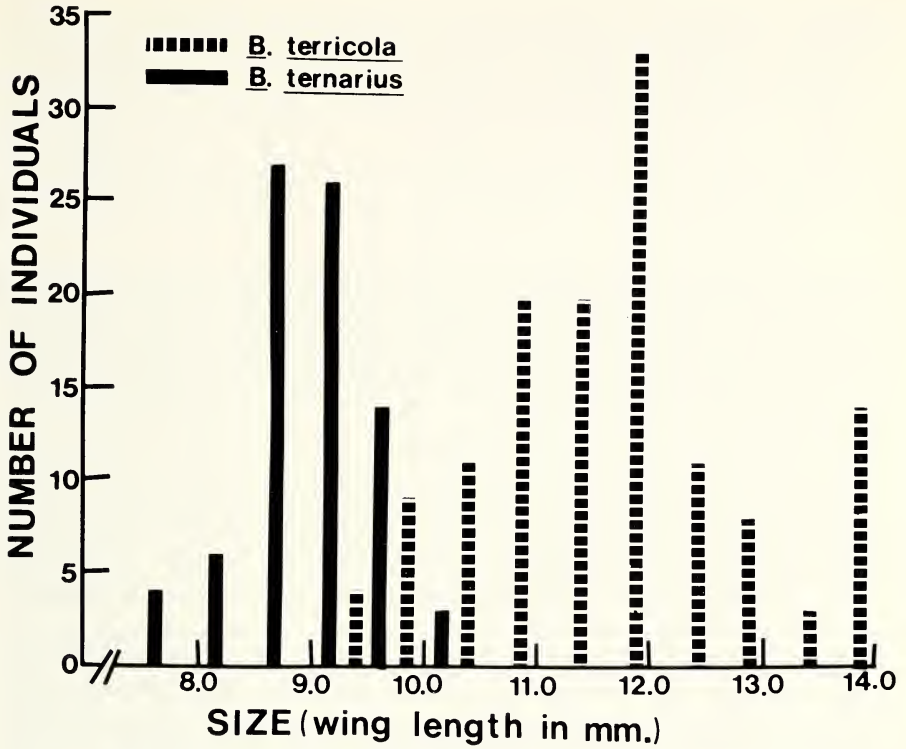

Fig. 1. Size of bumble bee workers in study area.

allowing it to forage for 30 s I counted the positions of the next 50 florets visited: whether they were located in the proximal, medial, or distal parts of the branches constituting the inflorescence (Morse, 1977). I scored each proximal observation 3, each medial one 2, and each distal one 1. Thus, any individual could receive a score as high as 150 or as low as 50. Simultaneously, I measured the time required by the bee to visit the 50 florets. About two-thirds of the individuals would readily forage under these circumstances. Those that would not forage were released from the cage, and new individuals were substituted for them.

I then introduced other bees in various combinations and allowed all individuals to forage in the cage for three minutes, which should insure that they were aware of each others' presence. Then I measured the foraging patterns of the first-introduced individual in the same way that I did several minutes earlier. For controls I ran experiments similar to those just outlined, except that I did not introduce additional bees prior to the second set of observations. Typically I ran 10 or more replicates for each set of experiments.

Table 1. Percentages of common bumble bees (*Bombus*:*Apidae*) in study area.

Year	Number of counts	*B. terricola*	*B. ternarius*	*B. vagans*
1975	15	67.2	17.3	15.5
1976	7	50.6	21.5	27.9
1977	12	79.0	10.5	10.5

To test for the possibility of cage effects I compared data gathered in the experiments with similar observations that I made of free-ranging individuals in the field. The observations of free-ranging bees were made upon the same marked individuals that were tested in the cages.

Results

Abundance and size of the bumble bees.—*Bombus ternarius* and *B. terricola* are two of the commonest large pollinators of goldenrod along the Maine coast, where I conducted this study. *Bombus ternarius* workers are much smaller than those of *B. terricola* on the average (Fig. 1), although some overlap occurs.

A third species of bumble bee, *B. vagans* Smith, occurs in numbers comparable to those of *B. ternarius* (Table 1), but after the early part of the goldenrod season its numbers decline. In addition, yellowjackets, *Vespula* spp., and syrphid flies, primarily *Toxomerus marginatus* (Say), are often in attendance.

Foraging locations.—When *B. ternarius* workers were run in these experiments with larger *B. terricola* workers, the *ternarius* workers foraged more distally than they did when alone (Table 2). This pattern held without exception in the tests using three *terricola* workers. In experiments using a single *terricola*, a trend occurred for *ternarius* to forage more peripherally with the *terricola* than when alone, but this difference was not significant at the 0.05 level.

Table 2. Foraging scores of *Bombus ternarius* workers on 50 florets of goldenrod.

Treatment	*n*	score $\pm$ 1 SE_m	P^a
Before *Bombus terricola* added	12	90.4 $\pm$ 1.9	<0.003
No *B. terricola* added, 5 min later		99.1 $\pm$ 3.0	
Before *B. terricola* added	10	96.5 $\pm$ 1.6	>0.05
After one *B. terricola* added		90.4 $\pm$ 3.1	
Before *B. terricola* added	10	96.1 $\pm$ 1.7	<0.003
After three *B. terricola* added		79.4 $\pm$ 1.8	

[a] One-tailed Wilcoxon Test.

Table 3. Foraging scores of *Bombus ternarius* workers on 50 florets of goldenrod.

Treatment	*n*	score ± 1 SE_m	P^a
Before *Bombus terricola* added		96.4 ± 2.1	>0.05
Flying free in field		92.9 ± 2.8	

[a] One-tailed Wilcoxon Test.

To insure that these changes were not simply a function of the time that individuals had been feeding on a clump of goldenrod, I compared the foraging patterns of individuals that had been in the cage for several minutes with the patterns that they exhibited shortly after introduction. A significant tendency actually occurred to forage more medially after having been in the cage for this period of time. Thus, the results obtained from introducing *terricola* were conservative, in that the peripheral shifts observed counteracted a tendency to forage more medially after working on a clump of goldenrod for several minutes. These three sets of data (0, 1, 3 *terricola* added) differ highly significantly among themselves ($P < 0.001$) in a Kruskal-Wallis, one-tailed analysis of variance.

The replicates from the experiments in which one *terricola* was added were composed of two types of responses: cases in which sizeable shifts occurred to more distal locations after a *terricola* worker was introduced, and cases where slight (and probably random) shifts occurred either in a distal or proximal direction (+1,–1,+3,+6,+8,–8,–9,–18,–20,–23). While I did not record precise observations on the location of the two performers in these experiments, in at least two cases where no marked shifts occurred the *ternarius* and *terricola* foraged at the opposite extremities of the clump of goldenrod, and in at least three cases where marked foraging shifts occurred the individuals foraged close to each other at least half of the time. More observations of this sort are needed.

Several individuals tested in the cages were also observed when in the field, and similar data were obtained. These individuals did not feed in significantly different locations from where they foraged when in the cages (Table 3).

To test the effect of *ternarius* upon the foraging of large *terricola* I ran similar tests in which a large *terricola* was first allowed to forage and then a *ternarius* worker was added. As a control I ran the *terricola* in the absence of *ternarius*, similarly to the reciprocal experiments.

Large *terricola* showed no tendency to change their foraging patterns when in the presence of *ternarius* (Table 4). Neither did a tendency occur for them to change their foraging patterns in the cages after a period of time had elapsed (Table 4). I did not run large *terricola* workers against three *ternarius* workers because I did not observe any combinations of free-ranging bees on goldenrod clumps that approached this ratio.

Table 4. Foraging scores of *Bombus terricola* workers on 50 florets of goldenrod.

Treatment	*n*	score ± 1 SE_m	P^a
Before *Bombus ternarius* added	9	102.3 ± 1.9	>0.05
No *B. ternarius* added, 5 min later		102.4 ± 2.2	
Before *B. ternarius* added	10	106.4 ± 2.2	>0.05
After one *B. ternarius* added		105.0 ± 2.9	

[a] One-tailed Wilcoxon Test.

Rate of foraging.—What is the cost to *ternarius* of *terricola*'s presence? One way to determine this cost is to measure the time required for *ternarius* to forage in the different areas. I assume that handling time per floret is solely a function of the time required for an individual to position itself and to probe a floret with its proboscis. Since individual goldenrod florets produce extremely small volumes of nectar (Heinrich, 1976), the amount of liquid potentially available should be absorbed instantly through capillary action (see Inouye, 1976).

No significant difference existed in the overall rates at which *ternarius* foraged by themselves in the initial runs and afterward in the presence of one *terricola*, three *terricola*, or by themselves (Table 5). When *ternarius* foraged in their initial runs there was no correlation between their rate of visiting florets and where the florets were located on the goldenrod. However, when with three *terricola*, those *ternarius* individuals foraging most distally visited florets at a significantly greater rate than did those feeding more proximally (Fig. 2). Those *ternarius* individuals foraging with a single *terricola* showed a slight but non-significant trend to forage most rapidly when in a distal position (Fig. 2). When tested against themselves five minutes after the first runs, distally foraging *ternarius* tended to forage more slowly, although not significantly so, than did individuals foraging more proximally. These three sets of data points differ highly

Table 5. Foraging rates (s) of *Bombus ternarius* workers on 50 florets of goldenrod.

Treatment	*n*	s ± 1 SE_m	P^a
Before *Bombus terricola* added	12	120.8 ± 5.8	>0.05
No *B. terricola* added, 5 min later		113.5 ± 5.1	
Before *B. terricola* added	10	78.2 ± 3.9	>0.05
After one *B. terricola* added		84.4 ± 2.3	
Before *B. terricola* added	12	110.2 ± 5.5	>0.05
After three *B. terricola* added		115.3 ± 6.7	

[a] One-tailed Wilcoxon Test.

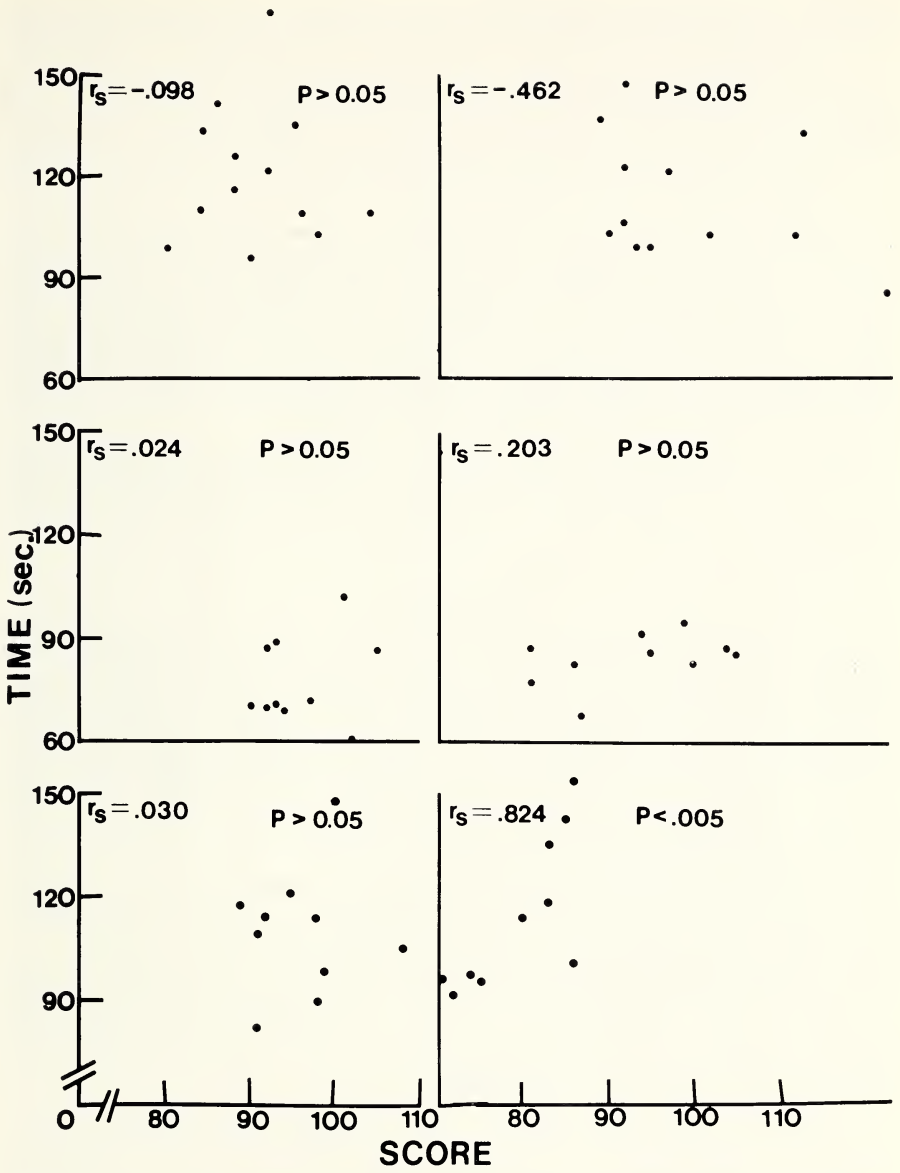

Fig. 2. Correlation between position on inflorescence and time required for *Bombus ternarius* workers to visit 50 florets. A–C = foraging patterns of *B. ternarius* alone shortly after introduction to test cage; D = foraging pattern of *B. ternarius* plotted in A five minutes later, with no *B. terricola* added; E = foraging pattern of *B. ternarius* plotted in B after one *B. terricola* added; F = foraging pattern of *B. ternarius* plotted in C after three *B. terricola* added. Significance levels refer to one-tailed Spearman Rank-Correlation Tests in each case.

Table 6. Foraging rates (s) of *Bombus ternarius* workers on 50 florets of goldenrod.

Treatment	*n*	s ± 1 SE_m	*P*[a]
Before *Bombus terricola* added	12	109.8 ± 4.5	>0.05
Flying free in field		99.8 ± 5.4	

[a] One-tailed Wilcoxon Test.

significantly among themselves ($P < 0.001$ in a Kruskal-Wallis, one-tailed analysis of variance), strengthening the initial observation that the best opportunity for rapid foraging by *ternarius* is in the distal areas when *terricola* is present in high densities. Although *ternarius* foraged somewhat more rapidly in the field than in cages, considerable scatter occurred, and the differences were not significant (Table 6).

Large *terricola* workers foraged at the same rate with a single *ternarius* that they did when by themselves (Table 7). Neither did they significantly change their foraging rates after being alone in the cage for several minutes (Table 7).

Discussion

These results support the hypothesis that large *terricola* spatially displaced *ternarius*. The effect was most pronounced when *terricola* were at high, although not unnaturally high, densities. When *terricola* were at lower densities, crowding was apparently not high enough to produce this effect in every case. *Bombus ternarius* that came in close contact with large *terricola* workers under the latter circumstances responded in the same way that they did in the high-density runs.

Bombus ternarius did not noticeably affect the foraging of *terricola*. Given the usual social superiority of large individuals over small (Morse, 1974), this result is not surprising, but one that cannot simply be assumed.

The results further indicated that *ternarius* foraged with equal facility on all parts of the inflorescence when by itself. However, when with large numbers of *terricola* it retained this rate only when concentrating its activities on the distal parts of the inflorescences.

Table 7. Foraging rates (s) of *Bombus terricola* workers on 50 florets of goldenrod.

Treatment	*n*	s ± 1 SE_m	*P*[a]
Before *Bombus ternarius* added	10	89.4 ± 3.8	>0.05
No *B. ternarius* added, 5 min later		93.3 ± 3.3	
Before *B. ternarius* added	9	103.8 ± 6.2	>0.05
After one *B. ternarius* added		102.6 ± 5.5	

[a] One-tailed Wilcoxon Test.

Seventy percent of the combinations of bumble bees naturally occurring on goldenrod clusters were less extreme than the 3 *terricola*:1 *ternarius* ratio tested, and only 13 percent of the combinations were more extreme than this (Morse, unpublished data). These ratios suggest that *ternarius* may have avoided flower clumps upon which *terricola* were particularly dense, but I have not yet tested this possibility.

Simultaneous observations indicate that avoidance of *terricola* by *ternarius*, rather than overt aggression on the part of *terricola*, is the mechanism responsible for this partitioning. I have not observed bumble bees to attack each other on goldenrod, although I have seen such interactions on flowers and artificial food sources that provide individual rewards much greater than those of goldenrod (Morse MS). When they confronted large *terricola* head-on, the *ternarius* retreated rapidly. I made 4 such observations in the experiments. The *terricola* gave no obvious response at such times. These shifts do not result from *terricola* exploiting resources in areas that would otherwise be exploited by *ternarius* (Morse, 1977).

I have dealt here only with interactions between *ternarius* workers and large *terricola* workers. Relationships between small *terricola* workers and *ternarius* workers (which are all small) may reveal a different pattern, but I have not yet completed these experiments. Nevertheless, the results presented account for a large part of the possible interactions between the two species, because of the minimal overlap in size. As a result, these data go a long way toward assessing the importance of these two species on each other. The precision of this assessment should improve as I complete more parts of this picture (*ternarius* vs. small *terricola*). Since goldenrod is the primary food source for both *ternarius* and *terricola* in the study area during August, an estimate of their impact upon each other on goldenrod accounts for most of their interactions. Further, in the study area *ternarius* in large part concentrates on goldenrod, with the number of individuals seen on these flowers considerably exceeding the total seen on all other flowers during the summer. Thus, the interactions on goldenrod are a vital aspect of *ternarius*' existence.

Acknowledgments

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FORAGING BEHAVIOR OF BUMBLEBEES ON FALSE FOXGLOVE

Edmund W. Stiles

There is a large body of recent literature exploring the theoretical aspects of foraging behavior (Emlen, 1966; Schoener, 1971; Pulliam, 1974; Krebs, Ryan and Charnov, 1975; Orians and Pearson, 1977). Field tests of these theoretical treatments are few, however, as the measurement of parameters to test predictions from theory is in many cases difficult. Bumblebees possess many characteristics which make them good subjects for foraging behavior studies including ease of field observation, quantifiable resource levels and abundance of individual foragers.

Foraging behavior in bumblebees may be analyzed by providing answers to four basic questions:

1. What types of food are used?
2. Where do bees forage or which resource patches do they select?
3. How long do the bees remain in a patch?
4. What are the patterns of speed and direction of movement within and between patches?

I will give a preliminary report on work examining aspects of speed and direction of movement of three species of bumblebees foraging on False Foxglove (*Aureolaria pedicularia*) in the New Jersey Pine Barrens.

Study Site and Methods

The study site was an Oak-Pine forest (McCormick and Jones, 1973) in Lebanon State Forest, New Jersey. This area is control-burned at least every third year and contains large stands of *Aureolaria pedicularia*. A 10×10 m grid was established in a large single-species stand of *Aureolaria* and grid squares were marked with numbered stakes. The number of flowers in each grid square was counted every morning.

Foraging was recorded by noting the species and sex of the bee, the time of day, the sequence of grid squares visited and the number of flowers within each square that was visited. For each flower visit I also recorded the activity of the bee at the flower, collecting nectar, collecting pollen, robbing, or any combination of these. The total time of an observation from when the bee was first sighted to the time the bee left the grid was also recorded.

Study Organisms

Aureolaria pedicularia (L.) Raf. is a much-branched annual reaching 1 m in height. In the New Jersey Pine Barrens it flowers from late August to late September bearing yellow, zygomorphic, campanulate flowers. The flowers are 3–4 cm in length and last for one day. Floral density during the one month study period reached as high as 1584 of these large flowers on the 10 × 10 m study grid. The flowers offer large quantities of pollen and nectar and are visited regularly by three common species of bumblebees.

The three species, *Bombus impatiens* Cresson, *B. vagans* Smith, and *B. affinis* Cresson, were common foragers on the grid being represented by both males and workers. Males of *B. vagans* were rarely found foraging on *Aureolaria*, using primarily other plant species in the area. The data for males of this species will be included even though sample size were low. *B. vagans* was the smallest of the three. *B. impatiens* was intermediate, while *B. affinis* was the largest species foraging on the grid.

Results

For the three species of bumblebees studied and for both males and workers I made the following computations:

1. The average time spent per flower, evaluating the speed of foraging while in the grid.
2. The total flowers visited divided by an index of the potentially available flowers. {If F_i = flower density in grid square i and D_i = the straight-line distance traveled by the foraging bee in grid square i, then the Index of Potentially Available Flowers = $\sum(F_i \times D_i)$}.
3. The total distance traveled within the grid divided into the straight-line distance from the point of first observation of the bee to the point of exit from the grid. This evaluates the degree of curvature of travel of bees foraging in the grid. A value of 1.0 would mean the bee traveled in a straight line.

All foraging observations which I will use here to compare species foraging behavior are of bees robbing nectar. By 10:00 AM virtually all the flowers that had opened that morning had holes cut in the base of the corolla tubes which the bees used for robbing nectar. The largest species, *B. affinis*, is a primary nectar robber and cut holes in the bases of the corolla tubes to obtain nectar. A soldier beetle, *Chauliognathus pennsylvanicus* DeGreer (Cantharidae), was also common on the flowers and was also a primary nectar robber. The other two species of bumblebee did not cut holes in the flowers, but used the holes freely to obtain nectar after they

Table 1. Speed of movement as the average number of seconds spent per flower visited, Path Width as the flowers visited divided by an index of potentially available flowers and Curvature as the straight-line distance from first observation to leaving the grid divided by the total distance traveled for three species and two sexes of bumblebees.

	Bombus impatiens		*Bombus vagans*		*Bombus affinis*	
	♀	♂	♀	♂*	♀	♂
Speed	7.6	7.4	6.8	2.6	6.5	5.7
Path Width	.20	.18	.22	.21	.27	.19
Curvature	.19	.22	.35	.37	.38	.42

* Sample size inadequate.

had been cut. The observations compared here are of similar foraging behaviors in the three species.

Speed of foraging was slower for *B. impatiens* than for the other two species (Table 1). The number of seconds spent per flower includes the time spent on the flower plus the time spent flying to the next flower. Time in flight, however, was small relative to the time spent on the flower and the difference reflects the difference in feeding behavior on the flowers. In all three species, the males foraged faster than the workers. Additional data, however, will be needed to substantiate the difference in foraging speed in *B. impatiens*.

An evaluation of foraging path width was made by dividing the number of flowers visited by the index of potentially available flowers. Of the workers of the three species, *B. affinis* visited the widest path, *B. vagans* the next widest and *B. impatiens* the narrowest. In comparison with workers, males of all three species foraged using narrower paths (Table 1).

The curvature of flight path was measured for all species. *B. impatiens* workers showed the greatest degree of path curvature having almost twice that of *B. affinis* workers. Males for all species showed lower degrees of curvature than workers of the same species (Table 1).

Discussion

The behavioral difference among the three species and two castes of bumblebees are being analyzed in greater detail and the temporal analysis of changes in behavior with changing flower densities will be presented elsewhere. The implications that surface from the information presented above are applicable to the theory of central-place foraging (Orians and Pearson, 1977). Central-place foragers search for resources which they bring to some central place to store or feed young. The travel parameter in

the optimal foraging equation (see Schoener, 1971, for review) is of greater importance than for a non-central-place forager. In light of this, bumblebees make excellent subjects with which to compare central-place and non-central-place foraging for worker bumblebees are central-place foragers and male bumblebees are not.

Movement away from the central place, or nest, is important for the central-place forager because of the energy necessary for the return trip with a load of food. One can predict that there should be selection to modify foraging behavior to minimize return traveling distance in worker bumblebees. Optimal foraging theory without central-place foraging constraints would predict that straight-line movement would, on the average, result in more energy per unit time for a foraging bee due to the reduced probability of visiting the same flower twice. Central-place foraging predicts, however, that the worker bee should either travel in a more curved path or visit a wider path of flowers within a patch or both. These behavioral modifications will reduce the distance moved away from the central place for the same number of flowers visited.

Both the data on path width from measures of the flowers visited divided by the potentially available flowers and the data on the curvature of path support the prediction that workers, more than males, forage in a fashion that would reduce the energy necessary to return to a central place. Males of all three species exhibit use of narrower paths and have less curvature to their foraging paths when foraging through a grid of *Aureolaria pedicularia*.

This provides additional support for work done by Stiles on alder forest birds (in press) and G. H. Orians on Brewer's Blackbirds (personal communication) demonstrating the behavioral modifications of central-place foragers.

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RESOURCE PARTITIONING IN BUMBLEBEES

David W. Inouye

Current ecological dogma holds that if two or more closely related species coexist, there must be some mechanism which permits them to avoid competitive elimination. There is usually assumed to be a limit to the variety and abundance of resources, implying that continued coexistence is only permitted by differences in the resource utilization of different species. Thus, field studies of resource partitioning are expected to, and usually do, produce results which show regular, sometimes even predictable (e.g., Pulliam, 1975) patterns of resource utilization. These patterns may be determined directly, but are more frequently inferred from differences in morphological characters which are assumed to reflect patterns of resource utilization. This report describes such morphological differences in bumblebees, and their validity as indicators of resource utilization.

In a variety of bumblebee guilds, there appears to be a limit of three or four species which can stably coexist (Inouye, 1976, 1977; Brian, 1957; Pyke, personal communication; Heinrich, personal communication; Morse, personal communication). One resource which these species can potentially partition is food, the flowers from which they collect pollen and nectar. Because pollen is often collected coincidentally with nectar, and because the morphological indicators chosen for this study do not appear to affect pollen collection, the relationship between proboscis length and corolla tube length will be assumed to be the most important one in the partitioning of food resources. Proboscis length, as a morphological constraint, will be assumed to reflect the portion of the resource continuum of corolla tube length which a bumblebee species utilizes.

The ratios between measurements of proboscis length of a caste of coexisting species generally fall in the range of 1.2–1.4 (Inouye, 1977). This observation, which appears to be valid for bumblebees in both North America and Europe, is consistent with the empirical observations that in a wide variety of organisms, otherwise similar species differ in the size of the feeding apparatus (or some morphological trait correlated with feeding) by a constant factor of 1.2–1.4 (Schoener, 1974).

The use of proboscis length as a morphological indicator of resource utilization is easily justified. Obviously, a bee species with a proboscis length of x mm cannot usually extract nectar from a corolla tube of length greater than x mm. Even on a more refined level, however, the relationship between proboscis length and corolla tube length is important. For a given flower size, the correlation between proboscis length and time spent per flower (assumed to be primarily a reflection of handling time,

rather than extraction time) is positive, with a significant regression line and correlation coefficient (Inouye, 1976, 1977). Correspondingly, for a given bee species foraging on a variety of corolla tube lengths, the correlation between corolla tube length and time per flower is negative, again with a significant regression line and correlation coefficient (Inouye, 1976, 1977).

Some species of bumblebees are more flexible in their foraging behavior than the majority of species, and may forage by nectar robbing, biting holes through the corolla tubes instead of foraging legitimately and pollinating the flowers (Inouye, 1978). If such species are not restricted to a particular segment of the resource continuum, they might be able to coexist with species of similar proboscis length but which do not exhibit the behavior of nectar robbing. That this is indeed the case is suggested by data from both Europe (Brian, 1957) and North America (Inouye, 1976, 1977; Morse, personal communication; Heinrich, personal communication; Pyke, personal communication) indicating that if more than three species of bumblebees coexist, the fourth is a nectar robber. Thus both morphological constraints and flexibility of foraging behavior appear to be important determinants of resource partitioning in bumblebees.

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Entomological Society of America
Eastern Branch Meeting
14–16 September 1977
Boston, MA

Symposium

DEVELOPING INSECT PEST MANAGEMENT SYSTEMS: RESEARCH REQUIREMENTS AND METHODOLOGIES

A. A. Hower and Z. Smilowitz, Moderators

Introduction

The past decade has produced many changes in our pest control strategies. We have gone from what can be considered a unilateral decision strategy with a primary reliance on chemicals for controlling insect pests to a systems approach. The strategy of an Insect Pest Management System (IPMS) differs from conventional control in that all available information and techniques are evaluated and consolidated into a unified program to manage insect pests in the most economical and ecologically compatible manner. Development of an IPMS requires obtaining a vast quantity of specific ecological data on the insects of the system and the economic bearing of the pest to production and control costs. The data must also be organized into a workable fashion for implementation. The systems approach thus requires considerably more information than conventional control strategies. Because of the broad scope of IMPS the best manner of discussing the system is to divide it into specific components. The major components as we visualize them today might be identified as (1) insect component, (2) plant component, (3) environmental conditions influencing both insect and plant, (4) economics of control, production, and marketing, and (5) the decision and implementation component, generated from the above data.

The objective of this symposium is to examine these components to see how research in an IPMS is initiated and the role classical entomologists can play in supplying data for the development of such systems.

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DEVELOPING THE INSECT MODEL

W. G. Ruesink

Models describing the dynamics of pest populations are important parts of a pest management research program, but unless we also have appropriate

plant models, it is difficult to understand or predict the impact of several pests occurring simultaneously on a crop. The development of the alfalfa weevil/alfalfa plant model illustrates one procedure which can be followed to obtain a systems dynamics model. The first step involved developing a flow diagram that included compartments for each component of the system and arrows connecting compartments to represent flows of materials or information. The diagram reflected our understanding of cause-effect relationships among components of the system. The next step involved writing equations for each component in the diagram. These equations were based on data from the literature and laboratory experiments, wherever possible, and described population processes and events in terms of rate functions for oviposition, mortality, development and feeding. By this time, several gaps in our knowledge had been revealed, and research was initiated to quantify the duration of diapause, adult longevity, and several other factors. The next step was to compare the model's performance, especially predictions of density versus time, with sampling data from field populations. When discrepancies were discovered, an effort was made to refine the faulty section of the model. In most cases, additional biological research was required to develop the necessary understanding, but at times an unsupported hypothesis was used with some success. For example, the model describes weevil oviposition rate as a function of stored food reserves that are depleted during winter and that must be restored to a minimum level in the spring before egg-laying can commence. We have no data to support the food reserve hypothesis, but after it was added to the model, the predicted spring egg densities agreed much better with the field data.

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ENVIRONMENTAL PARAMETERS AND THEIR USE

J. C. Allen

Most current insect development models predict the timing of developmental stages by heat unit accumulation. Simple linear heat units ("degree-day") are usually assumed although more complicated non-linear units may be necessary. Degree-days may be *approximated* by accumulating average daily temperatures above a threshold, but a more accurate method is to accumulate half-day areas under sine wave curves between thresholds. This method allows for different minima at each end of the daily temperature cycle, and regression methods can be used to correct for bias in different geographic areas.

When the dependent variable has no obvious zero time point or when

the process is obviously multi-variate, then other methods are necessary. An exponential model with a time-dependent rate is one approach having a multiple linear regression solution. The exponential equation takes the form

$$x_t = x_0 \exp\left[-\int_0^t f(t)dt\right]$$

where $f(t)$ is a linear sum of several cumulative time-dependent variables such as temperature, rainfall, vapor pressure deficit, etc. Taking logarithms to the base e gives:

$$\ln(x_t/x_0) = a_0 + a_1\int f_1(t)dt + \ldots + a_n\int f_n(t)dt,$$

a multiple linear regression of $\ln(x_t/x_0)$ on accumulated variables (e.g. heat units, cum. rainfall, etc. Similar reasoning can be applied to "logistic" equation,

$$p = 1/\{1 + \exp[-\int f(t)dt]\},$$

where p is a proportion in some growth or mortality process. This equation may be linearized as

$$\ln[(1-p)/p] = a_0 + a_1\int f_1(t)dt + \ldots + a_n\int f_n(t)dt$$

which is a multiple linear regression of $\ln[(1-p)/p]$ on accumulated environmental variables.

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DETERMINING ECONOMIC RELATIONSHIPS

W. L. Sterling

The term "action level" is proposed for general use as the estimate of the economic threshold. It might be defined as an empirically determined pest density at which some action tactic should be employed to prevent losses unacceptable to the producer or his decision-maker. "Action level" could thus be used to describe the pest densities at which management decisions are being made in most of our fledgling management programs. However, the continuing goal of pest management researchers should be to obtain the definitive economic thresholds and economic injury levels.

Some of the factors which should be considered in establishing economic thresholds include climatic conditions, phenological events, cultivars, crop cultural practices, economics, externalities, aesthetics, cumulative damage by all pests, plant compensation, insecticide resistance, geographical distribution of pests, produce quality, soil types, spatial dispersion, pest dispersal, natural mortality factors and pest density.

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PRODUCING DECISION AND DELIVERY SYSTEMS

G. P. Dively

Presented is an overview of decision and delivery systems used today in the 38 USDA-Extension funded IPM pilot projects, with emphasis on research needs.

Most projects rely on field scouting and trapping devices as means of providing decision-making information. Since the grower must ultimately be convinced that the risks and cost of scouting outweighs the benefits, much research needs to be done in developing more practical scouting techniques. Catch/damage relationships and the effects of weather on trap catch must be further investigated before traps can be fully implemented as decision-making tools.

Lack of decision-making methodology is perhaps the most limiting factor in developing IPM systems. Most projects rely on rigid economic thresholds and have demonstrated repeatedly that these guidelines are not flexible enough to account for the many changing factors of pest/crop systems. Several projects employ sliding thresholds and static decision-making models which vary with respect to crop maturity, days to harvest, moisture stress, beneficial insect density, etc. Timing (or phenological) models are used to predict critical events in the life cycle of insect pests which allows more precise timing of control strategies and also aids scouts in scheduling sampling activities. Development of such models is hampered by a lack of real-time weather data and knowledge of weather-dependent population parameters. More dynamic decision-making models are being developed which couple the population dynamics and feeding potential of the insect pest to the growth, development, and compensatory ability of the crop. Considerable work on key population processes must be done before models of this type can be developed. Especially needed is research aimed at developing plant models that describe the effects of insects on yield.

Information delivery systems include the traditional extension mechanism along with more modern telecommunication and computerized advisory networks. The main problem associated with implementing computerized delivery systems is the lack of decision-making models and alternative management strategies.

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INDEX TO SCIENTIFIC NAMES OF ANIMALS AND PLANTS VOLUME LXXXV

Generic names begin with capital letters. New genera, species, subspecies, and varieties are printed in italics. The following items and articles are not indexed: Diagnostic characteristics table in "A New Diagnostic Character in the Forewing of Apoidea (Hymenoptera)" U. N. Lanham. Pp. 98–100. List of species and Locality Records in "The Anthomyiidae and Muscidae of the Presidential Range in New Hampshire (Diptera)" H. C. Huckett. Pp. 130–142.

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