

ACARINA ASSOCIATED WITH MICHIGAN
BOMBINAE

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This is to certify that the

thesis entitled

ACARINA ASSOCIATED WITH

MICHIGAN BOMBINAE

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ABSTRACT

ACARINA ASSOCIATED WITH MICHIGAN BOMBINAE

by Robert W. Husband

This study is concerned with the distribution, associations and descriptions of Acarina found in or on Michigan Bombinae or in Bombinae nests.

Locality information for more than 15,000 Michigan Bombinae was used in determining Bombinae distribution. More than 6,000 Bombinae were collected since 1963. Mites were removed from bees and their nests and placed on slides or in 70% alcohol. Determinations were accomplished by the use of the available literature and all mites appearing in the thesis were determined or confirmed by the authorities which are listed.

Seventeen of 19 species of Bombinae in Michigan have ranges that terminate at latitudes within the state or at the borders. Bombinae distribution patterns appear to be most closely related to rodent distribution, the 70°F July isotherm, rainfall, vegetation, terrain elevation and host distribution for Psithyrus spp. Acarina were common to 26 of 27 Bombinae nests examined.

Techniques for examining Bombinae for mites are presented. Locustacarus (Bombacarus) buchneri (Stammer) 1951, new combination, is redescribed and discussed in detail. The relative

Robert W. Husband

abundance of Michigan Bombinae with mites is highest in April, steadily decreases until August and reaches a second peak in October. Queens and males in nests had a higher percent of infestation with hypopi. The propodeum and abdominal segment I are demonstrated to be the most likely areas for occurrence of mites and the areas most likely to bear the highest numbers of mites. A check list of twenty five families of mites found with Bombinae is provided. Distribution records and species associations of mites and bumble bees collected at flower and in nests are presented.

The distribution of Pneumolaelaps spp. in North America is discussed and Pneumolaelaps longanalis n.sp. (Acarina: Laelaptidae) is described. Kuzinia laevis and Scutacarus acarorum were found on most Bombinae throughout Michigan. Pneumolaelaps spp., Parasitus spp. and Proctolaelaps spp. occurred with less frequency. Locustacarus buchneri is relatively host specific and is found primarily in the air sacs of Bombus bimaculatus. Michigan mites found with Bombinae range from mites which feed upon decaying leaves in the nest to fungivorous, predaceous and parasitic mites.

ACARINA ASSOCIATED WITH
MICHIGAN BOMBINAE

By

Robert Wayne Husband

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ACARINA ASSOCIATED WITH MICHIGAN BOMBINAE

Introduction

Acarina were observed in bumble bee nests in America as early as 1863 (Putnam 1864). Since 1864, many incidental reports of mites in nests or on bumble bees have been made. Although some studies have been accomplished in Europe (Postner 1951), no intensive work on the mites associated with bumble bees exists in the Americas. The present work is concerned with the distribution, associations and descriptions of mites found in or on bumble bees or in their nests.

Inasmuch as the distribution, anatomy and biology of the Bombinae in Michigan are critical to the distribution of mites associated with them, this study will begin with a report of the present knowledge of Michigan Bombinae. The second part will consider various relationships of Bombinae and Acarina.

PART I - MICHIGAN BOMBINAE

The contributions in this study on Michigan Bombinae are unique to the extent that more recent data on systematics, distribution and possible environmental relationships are now available. The sections which follow provide a basis for discussion of mite and bee relationships.

METHODS AND MATERIALS OF DEALING WITH BOMBINAE

Locality information for more than 15,000 Michigan Bombinae was used to determine the ranges of the seventeen species which occur in Michigan. Approximately 11,000 bumble bees are in the Entomology Museum at Michigan State University and the remaining specimens are in the Museum of Zoology,

University of Michigan. I have collected approximately 6,000 bumble bees in Michigan in the past three years. Determinations were made by utilization of several published and unpublished keys and by comparison with specimens identified by Frison, Franklin, Milliron and others. In some cases, genitalia were removed. In a few cases, genitalia were preserved in alcohol or put on slides. The keys used are by Chandler (1950), Fischer (unpublished key to workers), Franklin (1913), Medler and Carney (1963) and Milliron (1939, 1961). The bees are deposited in the Museum of Entomology, Michigan State University and the Museum of Zoology, University of Michigan.

ANATOMY OF BOMBINAE

Mites crawl over all external structures of bumble bees but are more commonly found in definite areas on the bees. A brief generalized description of the anatomy of the bumble bee will facilitate the identification of the areas of potential mite infestation.

A female Bombus nevadensis is chosen for illustration as females are much more likely to be encountered. Males and female Psithyrus sp. lack the pollen basket (corbicula) on the metatibia (figure 1). Males possess an additional antennal segment and abdominal segment. The terminology of various structures is based on terms common to various keys to Bombinae and terms used by Snodgrass (1956). Terms in common use in keys are employed when conflicts are found. A queen Bombus nevadensis with hairs removed is the model

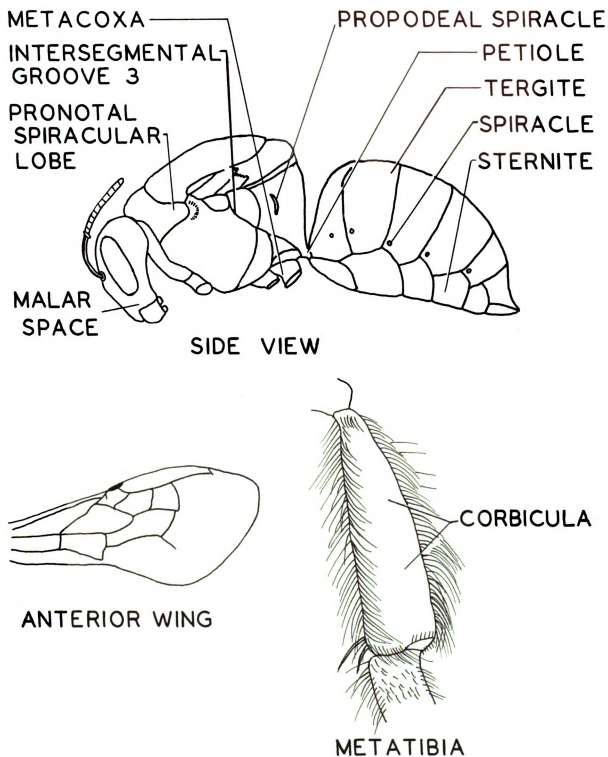


Figure 1. *Bombus nevadensis*, female

for illustrating approximate positions of various anatomical structures. The proportions of the various parts differ from species to species but one set of terms is sufficient for describing the positions of mites on bees.

A side view of Bombus nevadensis is illustrated in figure 1. A view of the front wing and hind tibia are included as these are common sites of acarid mite attachment. As mites are rarely found on the head, a detailed description is not given. The terminology necessary for understanding the keys to species of Bombinae are presented in the next section.

The thorax of the adult bumble bee is composed of four segments. The propodeum which constitutes the fourth thoracic segment of Bombinae is the first abdominal segment of many insects. The prothorax is small in comparison to the rest of the thorax. The procoxae and profemora fit into a groove in the sides of the prothorax. The spiracle between the prothorax and the mesothorax is protected by stiff hairs and covered with the pronotal spiracular lobe. Dense body hairs are usually found posterior to the spiracle on episternite two. Thus, the spiracle is difficult to detect in Bombinae. The large mesonotum is divided into a scutum and scutellum (figure 2). The tegulae are sometimes confused with mites by the uninitiated. A major portion of the pleura and ventor is composed of fused sternites and episternites of the mesothorax. The third segment is reduced and separated from the propodeum by the third intersegmental groove. A large

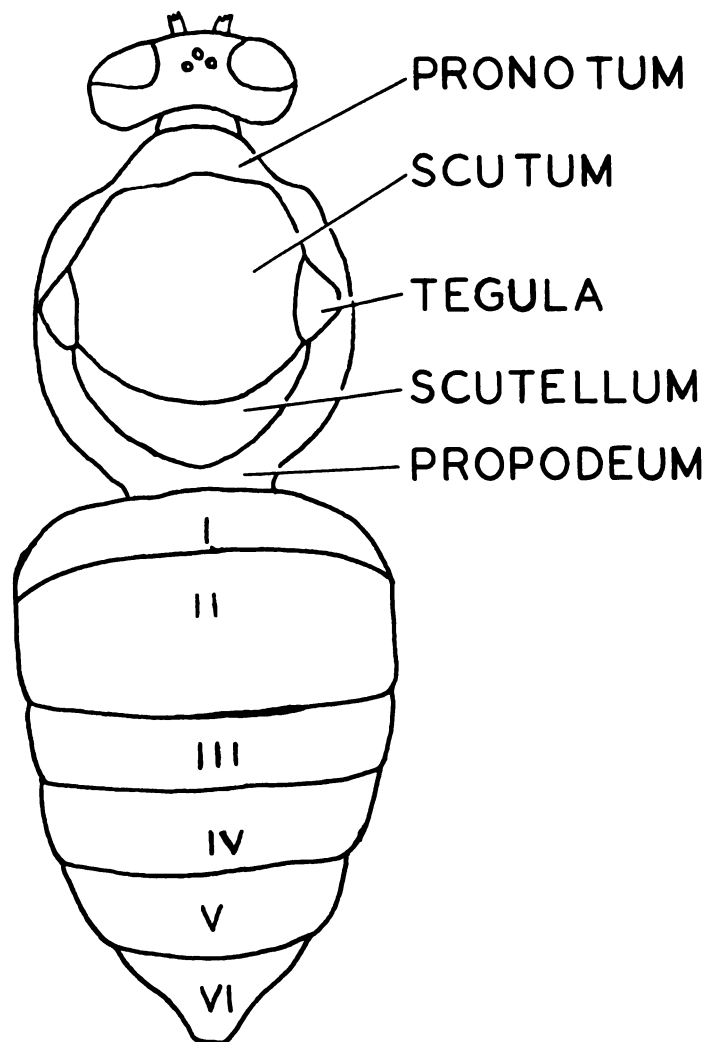


Figure 2. Bombus nevadensis, dorsal aspect, female

propodeal spiracle is found on the posteriolateral aspect of the thorax. A deep constriction separates the propodeum from the remaining primary abdominal segments. Inasmuch as the first segment posterior to the constriction is consistently named abdominal segment 1 in keys to bumble bees, to name this segment abdominal segment 2 (Snodgrass 1956) would result in unnecessary confusion. Ventrally, the propodeum is represented by a small sternite surrounded by non-sclerotized tissue (figure 3). The narrow connection of the abdomen and thorax is termed the petiole. Very small spiracles may be found at the sides of each abdominal tergite. The ventral sclerites are known as abdominal sternites.

SYSTEMATICS OF MICHIGAN BOMBINAE

While the systematics of various species of mites associated with Michigan Bombinae are poorly known, the systematics of Bombinae are fairly well known. Milliron (1939, 1961) published on this subject in recent times. The taxonomy used in this report differs from other publications in ignoring subspecies and color variants, in the omission of one species and the addition of another.

The sub-family Bombinae is one of the sub-families of the family Apidae. Bombinae may be distinguished from other Apidae by the presence of two apical spurs on the hind tibia. Other characteristics are: relatively large size, distinct malar space (distance between eye and base of mandible) in most and a distinct transection of the first submarginal cell.

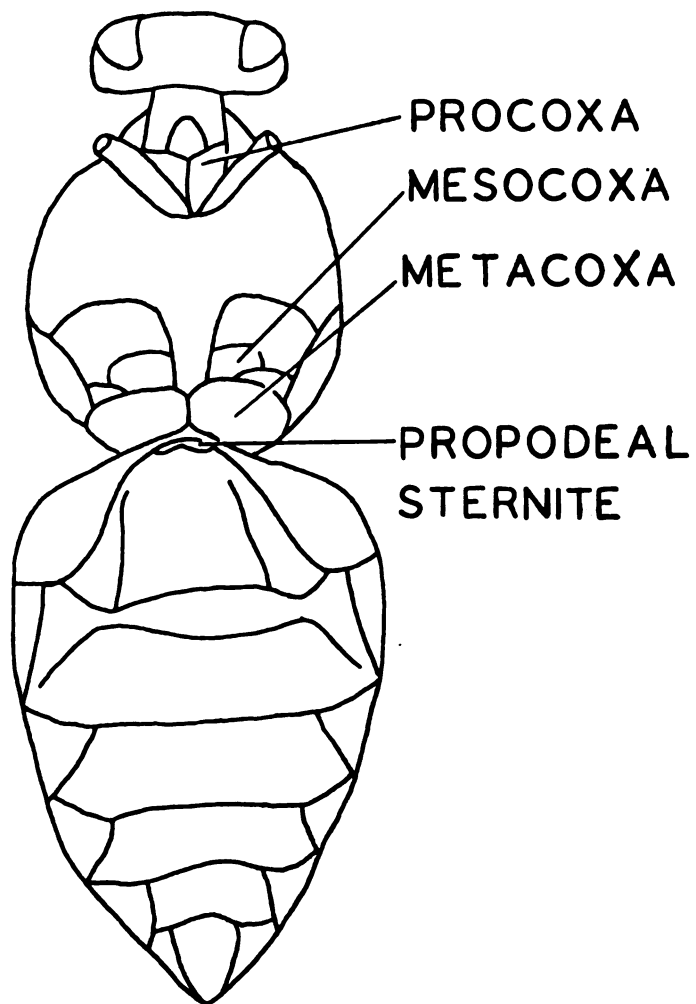


Figure 3. Bombus nevadensis, ventral aspect, female

Two tribes, Bombini and Psithyrini, are recognized (Milliron 1961). Bombini are social bumble bees and Psithyrini are their social parasites.

Female Bombini and Psithyrini have 12 segmented antennae, six visible abdominal tergites and the last abdominal segment is pointed. Female Bombini possess a corbicula on the outer surface of the metatibia, wide, strongly curved mandibles and a rectangular labrum. In contrast, Psithyrini lack a corbicula, have long, weakly curved mandibles and a triangular labrum.

Male Bombini and Psithyrini have 13 segmented antennae, seven visible tergites and the last abdominal segment is broadly rounded. Male Bombini have distally widened metatibia with little or no hair on the outer surface--longer hairs on the lateral margins, closely spaced hair and shallow punctures on the head, the head triangular to oval in most and with strongly sclerotized genitalic volsella and squamae. Psithyrini males have a narrow metatibia uniformly covered with short hairs, more widely spaced hair and deeper punctures on the head, the head square to spherical, and with weakly sclerotized genitalic volsella and squamae.

For the purposes of this project, the familiar generic designation Bombus is used instead of utilizing Bombus, Megabombus and Pyrobombus as suggested by Milliron (1961). The reasons for utilizing a single generic taxon are familiarity with the generic taxon Bombus and reduction in complexity of names of bees with which mites associate. The basic

characteristics which resulted in the naming of three genera are not ignored and may prove to be important in showing patterns of mite-bee associations.

KEY TO SPECIES OF MICHIGAN BOMBINAE

The following key is not designed to cover the many previously described color variants found in Michigan. It is based upon keys by Fischer (unpublished), Chandler-Indiana (1950), Medler and Carney-Wisconsin (1963), Milliron-Michigan (1939) and upon specimens found in the Museums of Michigan State University and the University of Michigan. It includes Psithyrus variabilis since this species may be found in southern Michigan.

- 1 Twelve segmented antennae, six visible abdominal segments, abdomen with a conical tip possessing a sting....Female Bombus and Psithyrus.....2

Thirteen segmented antennae, seven visible abdominal segments, abdomen bluntly rounded apically, no sting...Male Bombus and Psithyrus.....3

- 2 Outer surface of metatibia bare with a fringe of long hairs on the lateral margins (corbicula), wide-strongly incurved mandibles, rectangular labrum...Bombus.....7

Outer surface of metatibia uniformly covered with hairs (no corbicula), narrower-weakly curved mandibles, triangular labrum...
Psithyrus.....25

- 3 Metatibia distally widened with little or no hair on the outer surface and long hairs on the lateral margins of some, closely spaced hair and shallow punctures on the head, hair with or without yellow hairs, strongly sclerotized genitalic volsella and squamae...Male Bombus.....4
- Metatibia uniformly narrow, covered with short hairs; more widely spaced hair and deeper punctures on the head; face without yellow hairs, weakly sclerotized genitalic volsella and squamae...Male Psithyrus.....30
- 4 Large bulging eyes, ocelli well below supraorbital line.....5
- Eyes not bulging, ocelli near supraorbital line.....7
- 5 Tergite I yellow; Basal middle of tergite II rusty, remaining tergites black...B. griseocollis (DeGeer), m.
- Not as above.....6
- 6 Tergites I, II, III yellow, remaining tergites black, large (usually over 16mm)...B. nevadensis Cresson, m.
- Not as above, smaller (usually less than 15mm)...B. rufocinctus Cresson, m.
- 7 Tergite I yellow, remaining tergites black...B. impatiens Cresson, m., f.
- Not as above.....8

- 8 Tergite I yellow, tergites II and III red-orange
or red, remaining tergites variable.....9
Tergites usually only yellow and black (some
variants have scattered rusty hairs)....10
- 9 Tergites I yellow, tergites II and III red-orange,
tergite IV black; wide, black interalar band form-
ing a distinct V on scutellum...B. ternarius Say,
m., f.
Not as above...B. rufocinctus m., f. (in part)
- 10 Pleura mostly black, yellow thoracic hairs not
extending much below anterior wing base.....11
Pleura mostly yellow, yellow hairs to or
nearly to leg bases.....16
- 11 Dorsum of thorax yellow...B. perplexus Cresson, f.
Dorsum of thorax with black.....12
- 12 Tergites I, II, III, IV yellow or red-orange...13
Not as above.....14
- 13 Face and occiput black, tip of abdomen red, yellow
or black...B. pennsylvanicus DeGeer
Face with (female) or without (male) yellow
hairs, occiput yellow, tip of abdomen black
... B. borealis Kirby, m., f.
- 14 Last two tergites with yellow on posterior margin,
tergite I black...B. terricola Kirby, m., f.
Last two tergites entirely black, tergite I
Usually with some yellow hairs.....15

- 15 Large ocelli well below supraorbital line, occiput yellow, tergite I black in middle...B. nevadensis f.
 Smaller ocelli near supraorbital line, occiput black, tergite I mostly yellow...B. pennsylvanicus f.
- 16 Tergite I yellow, tergite II with basal middle yellow or rusty, remainder of abdomen black.....17
 Tergites I and II mostly yellow.....19
- 17 Interalar space black...B. rufocinctus f. (in part)
 Interalar space mostly yellow.....18
- 18 Tergite II with rusty basal portion broadly curved to margins, the remaining posterior segments black, occiput black...B. griseocollis f.
 Tergite II with basal midian portion yellow, occiput yellow...B. bimaculatus Cresson, m., f.
- 19 Tergites I, II, III, IV entirely yellow...B. fervidus (Fabricius) m., f.
 Tergites I, II, III, IV not entirely yellow..20
- 20 Malar space wider than long or square, occiput mostly black, interalar blackspot or band.....21
 Malar space longer than apical width, occiput yellow, with or without interalar black spot23

- 21 Tergite I yellow, tergite II basal hairs usually orange, posterior margin of tergite II hairs with a distinct median notch, usually no yellow hairs on tergites IV, V, VI or VII...B. affinis Cresson, m., f.
 Tergite II without orange basal hairs or distinct posterior median notch, yellow hairs may be present on tergites IV, V, VI and VII22
- 22 Malar space square, head rounded...B. frigidus m., f.
 Malar space distinctly shorter than its apical width, tergite I yellow, tergite II with black hairs on posterior margin...B. rufocinctus m., f. (in part)
- 23 Female, yellow occiput, long malar space...B. vagans F. Smith, f.
 Male, yellow occiput, long malar space....24
- 24 Tergites III black, if tergite III yellow tergite VI also yellow...B. vagans f.
 Tergite III yellow, tergite VI black... B. perplexus m.
- 25 Yellow hairs of pleura not extending to leg bases..26
 Yellow hairs of pleura extending to leg bases.....27

- 26 Occiput largely black, tergite IV and apical sides of III and V yellow...P. ashtoni (Cresson), f.
 Occiput yellow, abdomen usually black and bare...P. variabilis (Cresson) f.
- 27 Tergite IV entirely yellow, hair above antennal bases black...B. fernaldae Franklin, f.
 Tergite IV mostly black, hair above antennal bases usually yellow.....28
- 28 Abdominal tergites black...P. laboriosus (Fabricius), f. (in part)
 Considerable yellow on tergite III, some yellow hairs may appear on tergites II and IV...29
- 29 Mesonotum with black hair, tergites II and IV with parallel lines of yellow hair at sides...
P. insularis (F. Smith), f.
 Mesonotum with few or no black hairs, tergite IV usually black...P. laboriosus f. (in part)
- 30 Yellow pleural hairs not extending to leg bases..31
 Yellow pleural hairs extending to leg bases..32
- 31 Third and fifth antennal segments equal..P. ashtoni m.
 Fifth antennal segment near twice the length of the third...P. variabilis m.
- 32 Tergite VII with a ring of orange (yellow-orange) hairs...B. fernaldae m.
 Tergite VII black.....33
- 33 Tergite IV entirely black...P. laboriosus m.
 Tergite IV with yellow at sides..P. insularis m.

DISTRIBUTION OF MICHIGAN BOMBINAE

Precise knowledge of the distribution of Bombinae is essential in order to understand the distribution of mites associated with them. The purpose of this section is to review and analyze what is known, to present the data collected and interpret the present knowledge of the distribution and abundance of Michigan Bombinae.

The distribution of Michigan Bombinae was first systematically studied by Milliron (1939) although Cockerell (1916) and Lutz and Cockerell (1920) did some work with Michigan Bombinae. Franklin (1913) listed 17 species of Bombinae from Michigan. Milliron (1939) listed 18 species including Bombus fraternus (F. Smith) on the authority of literature by Franklin and Frison and adding B. frigidus var. couperi to previous records. Mitchell (1962) lists B. fraternus from Illinois but not from Michigan. Specimens of B. fraternus collected in Michigan are lacking in Michigan collections. No B. fraternus were collected in the course of this study. Chandler (1950) reported two specimens, one from central Indiana and one from southern Indiana. Some doubt exists whether this species which is rare in Indiana and absent from Wisconsin is established in Michigan at the present time. B. frigidus couperi has not been collected in recent years and the presence of this species is uncertain. Hobbs finds B. frigidus above 4500 feet in the foothills near Alberta, Canada. Psithyrus variabilis which has been found in southern Wisconsin and in two Indiana counties near the

Michigan border has not yet been found in Michigan. Thus, the present Bombinae found consists of 17 established species and a possibility of 19 total species.

While useful in studies of broad areas, county information is not always sufficient when attempting to test the possible relationships of distribution of bees and factors such as terrain elevation, isotherms and distribution of other animals and plants. In far too many museum specimens of Michigan Bombinae, the county was used to designate the collecting site.

Latitude, longitude and all of the counties are illustrated in figure 4. Known collecting sites appear as small circles in figures 5 through 23. Lightly shaded counties are those in which Bombinae were reported by Milliron (1939). The darker shaded counties are additional records for these species. If no circles appear in a county, only county information was present on the insect label. The lack of shading on a county indicates that the species has not yet been collected in the county.

Several collecting trips have been made throughout central Michigan, and in the upper peninsula by T. W. Porter, R. L. Fischer, R. B. Willson, R. W. Husband and others. However, over 90% of the total specimens of Michigan Bombinae in Michigan collections are from the lower third of the state. All of the specimens which were collected in the course of this study are deposited in the Entomology Museum at Michigan State University. Specimens from the museums of

the University of Michigan and Michigan State University are included in the report.

Milliron used the categories rare, not common and common to indicate a rough index of relative abundance. Acknowledging the subjectivity of these categories based on personal observations, the only species that does not fit the designation given by Milliron in 1939 is Psithyrus laboriosus. Milliron listed P. laboriosus as not common but it is now represented by nearly as many specimens as Psithyrus ashtoni which is listed as "probably the most common".

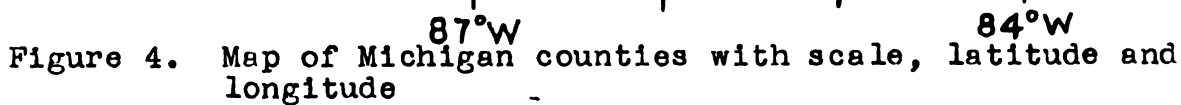




Figure 5. Distribution of Bombus affinis



Figure 6. Distribution of Bombus bimaculatus



Figure 7. Distribution of Bombus borealis



Figure 8. Distribution of Bombus fervidus



Figure 9. Distribution of Bombus frigidus

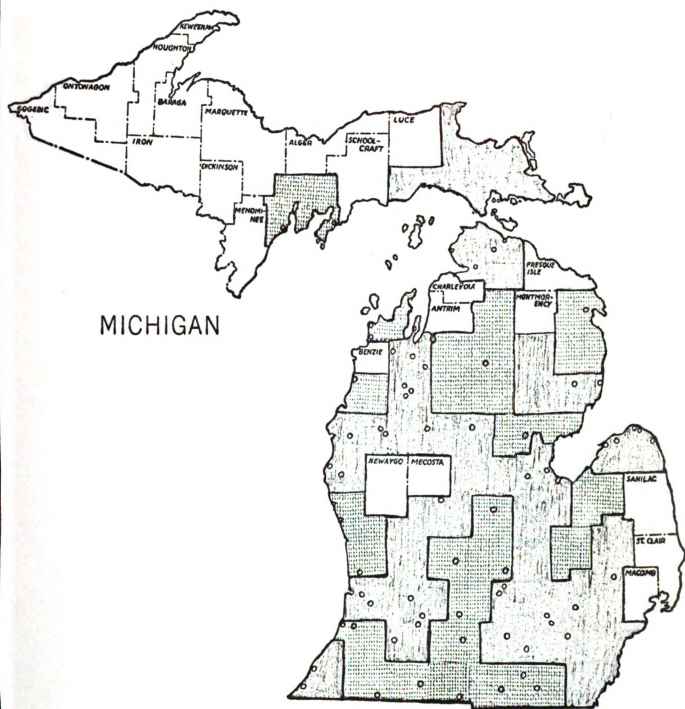


Figure 10. Distribution of Bombus griseocollis



Figure 11. Distribution of Bombus impatiens

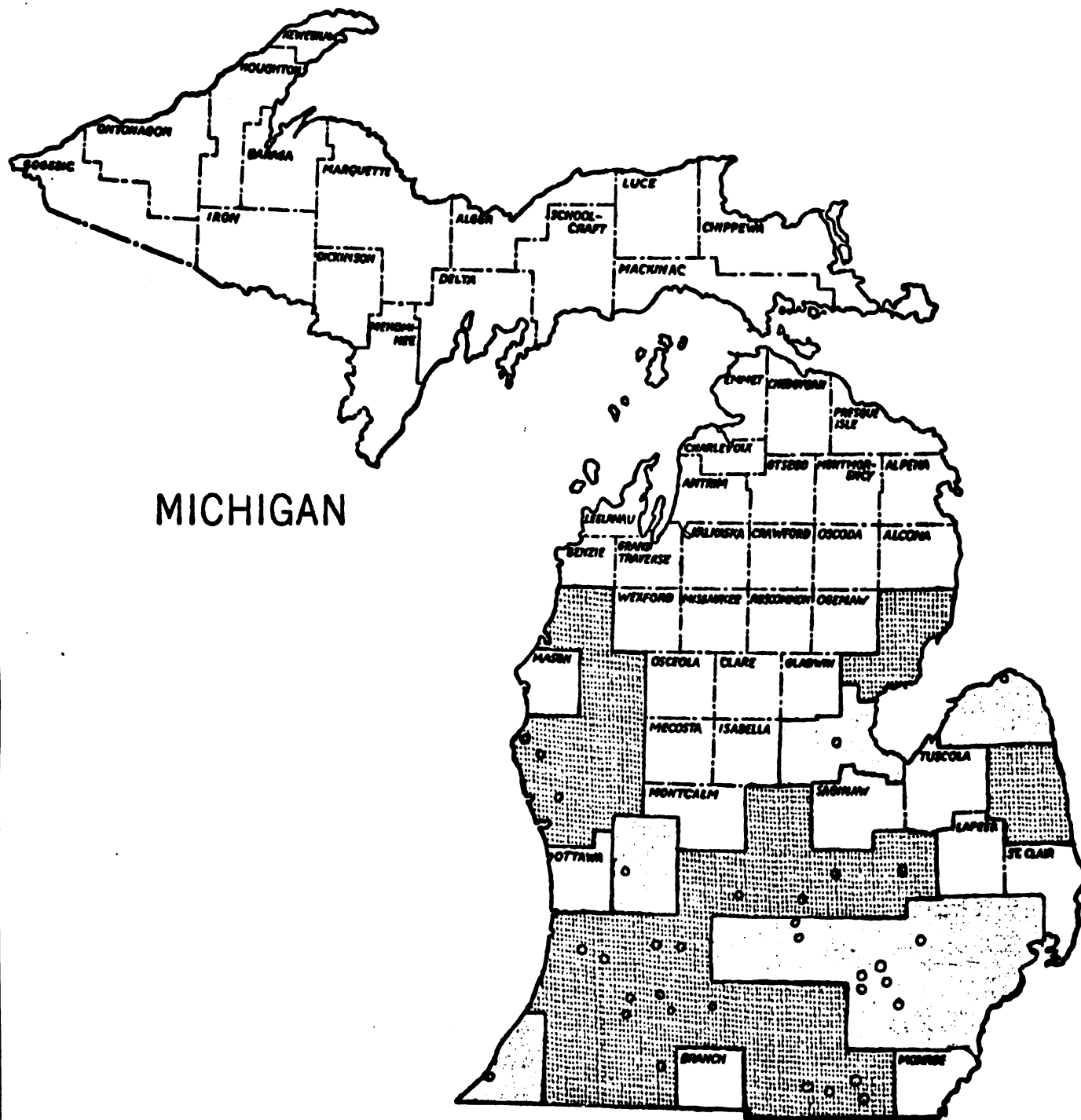


Figure 12. Distribution of Bombus nevadensis



Figure 14. Distribution of Bombus perplexus



Figure 16. Distribution of *Bombus ternarius*



Figure 17. Distribution of Bombus terricola

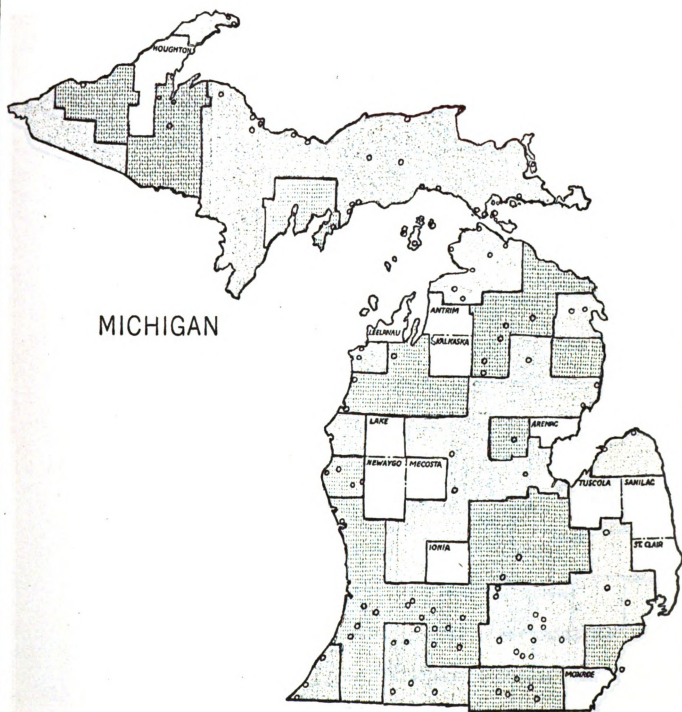


Figure 18. Distribution of *Bombus vagans*



Figure 19. Distribution of Psithyrus ashtoni



Figure 20. Distribution of Psithyrus fernaldae



Figure 21. Distribution of Psithyrus insularis



Figure 22. Distribution of Psithyrus laboriosus



Figure 23. Distribution of Psithyrus variabilis

DISCUSSION

The information concerning distribution of Michigan Bombinae has increased many times in the past twenty-five years. The collections of Michigan Bombinae in Michigan museums contain species of Bombinae from 385 counties in addition to the counties listed by Milliron (1939). In other words, 385 county records are contained in this report. More important, many areas are represented by long series of specimens and more specific locality information is known. Many entomologists have contributed to the records. Most of the additional records were collected by R. Dreisbach, R. L. Fischer, T. W. Porter and R. W. Husband.

Seventeen of the nineteen species of Bombinae listed in the preceding pages have ranges that terminate at latitudes within the state or at the borders. Thus, Bombinae are very useful in investigations of limiting factors and associated problems.

The center of the distribution of species is a useful category for analysis of distribution of Bombinae. If the center of distribution is south of Michigan, the term southern species is employed. If the center of distribution is within Michigan, the term cosmopolitan species is used. If the center of distribution is north of Michigan, the term northern species is used. Eastern or western categories are not used as east-west patterns of distribution are not apparent in Michigan or in adjacent states. The northern species are: Bombus borealis, B. frigidus, B. perplexus, B. rufocinctus,

B. ternarius, B. terricola, Psithyrus ashtoni, P. fernaldae and P. insularis. The cosmopolitan species are: Bombus affinis, B. fervidus and B. vagans. The southern species are: Bombus pennsylvanicus, B. nevadensis, B. bimaculatus, B. griseocollis, B. impatiens, Psithyrus laboriosus and P. variabilis. Following the possible origin of these species from either Eastern or Western Hemisphere as suggested by Milliron (1961), no apparent relationship appears to exist between the distribution of the bees in Michigan today and their possible origins. Thus, the Mendax line which is thought to have originated in the Eastern Hemisphere and moved into the Western Hemisphere in the Tertiary and Quaternary has the expected northern representative B. borealis but also includes the cosmopolitan B. fervidus and southern B. nevadensis. The entire state was covered by ice approximately 20,000 years ago and Bombinae populations have entered and reentered the area many times in the past million years. That present distributions are not clearly related to geographic origins a few million years ago is not surprising.

The ranges of Bombinae in Michigan have changed very little since 1939. Bombus borealis, although not common, has been frequently collected in recent years in the moraine areas of extreme southern Michigan. B. griseocollis and B. impatiens have been found along the southern coast of upper Michigan. Whether these are relict or pioneer colonies is not certain. Bombus rufocinctus appears less

frequently in the southern part of its range. Psithyrus ashtoni has been found further south than in previous times. One University of Michigan specimen is catalogued from Miller, Indiana. Chandler (1950) expressed doubt that this species occurs in Indiana. Psithyrus fernaldae has not been collected further inland than 16 miles from the coasts of the Great Lakes in Michigan. It has been found further inland in Wisconsin. Although the sample size for this species is low, this distribution pattern is rather unusual. Psithyrus insularis has been found much further south than previously recorded. This may be due to more extensive collecting in some areas since this species is rare. Psithyrus laboriosus was reported from one county in western Michigan in 1939. Now it is known to be common throughout the lower peninsula. Psithyrus variabilis is listed as one of the most common in Indiana (Chandler 1950) and has been collected in one county in Indiana on the Michigan border and another Indiana county close to the border. It may be moving northward in association with Bombus impatiens, B. pennsylvanicus and B. vagans which are very common in lower Michigan. Milliron (1939) listed B. frigidus from Isle Royale. The museum collections now include specimens of Bombus borealis, B. perplexus, B. ternarius, B. terricola, B. vagans, Psithyrus ashtoni and P. fernaldae.

ECOLOGICAL FACTORS WHICH MAY INFLUENCE BOMBINAE DISTRIBUTION

There are many factors which influence Bombinae distribution. This study is concerned with a few of these factors in Michigan. Rodents with which Bombinae may be associated and various climatic and geographic factors will be presented.

In other geographic areas, a few studies exist on such topics as diseases of Bombinae but it is not the purpose of this report to present an encyclopedia of all that is known about the ecology of Bombinae. Thus, while such factors as disease, predation, parasitism, interspecific competition and intraspecific competition may influence Bombinae distribution they are not the main subject of this report.

BOMBINAE AND MICHIGAN RODENTS

Bombinae frequently utilize rodent nests as nest sites. The skeletal remains of Peromyscus sp. indicates that Bombus fervidus may utilize nests of this genus. Plath (1934) suggests that rodents may destroy newly constructed nests while the queen is foraging. He also suggests that skunks and other mammals may destroy nests.

The ranges of several rodents terminate in the same geographic area as the ranges of several Bombinae. However, the relationship of Bombinae and rodents may not be a close one since Bombinae are not restricted to the selection of rodent nests as nest sites.

In figure 24, the northern boundary of the ranges of the following rodents are plotted: Rattus norvegicus Berkenhout, Mus musculus Linnaeus, Sciurus carolinensis Gmelin,

MUS MUSCULUS



Figure 24. Northern limits of selected Michigan rodents



Figure 25. Southern limits of selected Michigan rodents

Peromyscus leucopus Rafinesque, Citellus tridecemlineatus Mitchell, Sciurus niger Linnaeus, Glaucomys volans Linnaeus, Pitemys pinetorum LeConte and Pedomys ochrogaster Wagner.

In figure 25, the southern boundaries of the following rodents are plotted: Phenacomys intermedius Merriam, Microtus chrotorrhinus Miller, Eutamias minimus Bachman, Neozapus insignis Miller, Clethrionomys gapperi Vigors, Erethizon dorsatum Linnaeus, Glaucomys sabrinus Shaw and Castor canadensis Kuhl. The ranges in both figures read from north to south in sequence as the species are listed above and were obtained from Burt (1957). The ranges which very closely approximate ranges of species of Bombinae which are discussed in the next section. There are several species of rodents which are found throughout Michigan.

CLIMATIC FACTORS AND MICHIGAN BOMBINAE

Climatic factors and Bombinae distribution in North America have been discussed by Medler and Carney (1963), Neave (1933) and others. The comments of Medler and Carney are based in part on the observations of Curtis (1959) on Wisconsin zones. Curtis describes a tension zone running northwest to southeast in Wisconsin. The geographic limits of 182 species of plants are found in this zone. Fewer range boundaries are found on either side. Although such a study has not yet been completed for Michigan, there is considerable evidence that such a zone occurs in Michigan. In the early 1900's, Merriam et al. (1910) divided Michigan into Boreal, Transition and Upper Austral life zones. Dice (1943) divided the state into the Canadian Biotic province above a line from Ottawa County to St. Clair County and the Carolinian Biotic province below this line.

Curtis (1959) and others at Wisconsin studied a variety of climatic factors throughout Wisconsin. A few of the factors which tend to correlate with the tension zone are: average summer temperature of 67°F, average July temperature of 70°F (Medler and Carney 1963), average annual snowfall of 48", average evaporation in July of 5", and sixty days per year with average temperature of 68°F.

Much of the data on Michigan climate has been summarized from the U. S. Weather Bureau records by Senninger (1963). Other sources include the Michigan Freeze Bulletin (1965), McNeel and Goff (1961), U. S. Department of Agriculture (1941)

and recent records supplied by the U. S. Weather Bureau in East Lansing. Briefly, three large air masses are responsible for most of the weather in Michigan. A dry continental air mass from the west, a dry polar air mass from the north and a moist southern air mass. The prevailing winds are from the southwest. When the wind is strong semimarine weather exists. When no wind is present, continental weather patterns exist.

The majority of the precipitation occurs in the spring and fall as the warm moist air masses from the south are displaced upward when meeting the cold northern air masses. The winter periods are mainly under the influence of continental dry westerly or northern air masses.

Figure 26 shows the average July temperature during the years 1931-1960. The 70°F isotherm is indicated by a solid line. Figure 27 shows the average annual precipitation for the years 1931-1960. The U. S. Department of Agriculture (1941), using averages from an earlier period published similar map although the climate was less moist during that period. The area with less than 30 inches of precipitation is displayed with light shading. The area with over 35 inches is displayed with dark shading. Figure 28 shows the average date of the last temperature of 32°F or lower in the spring. Areas which have a date between May 10 and 20 are displayed with light shading. Areas with a date before May 10 are displayed with dark shading. No shading indicates the last date of 32°F is between May 20 and June 19. Figure 29 indicates

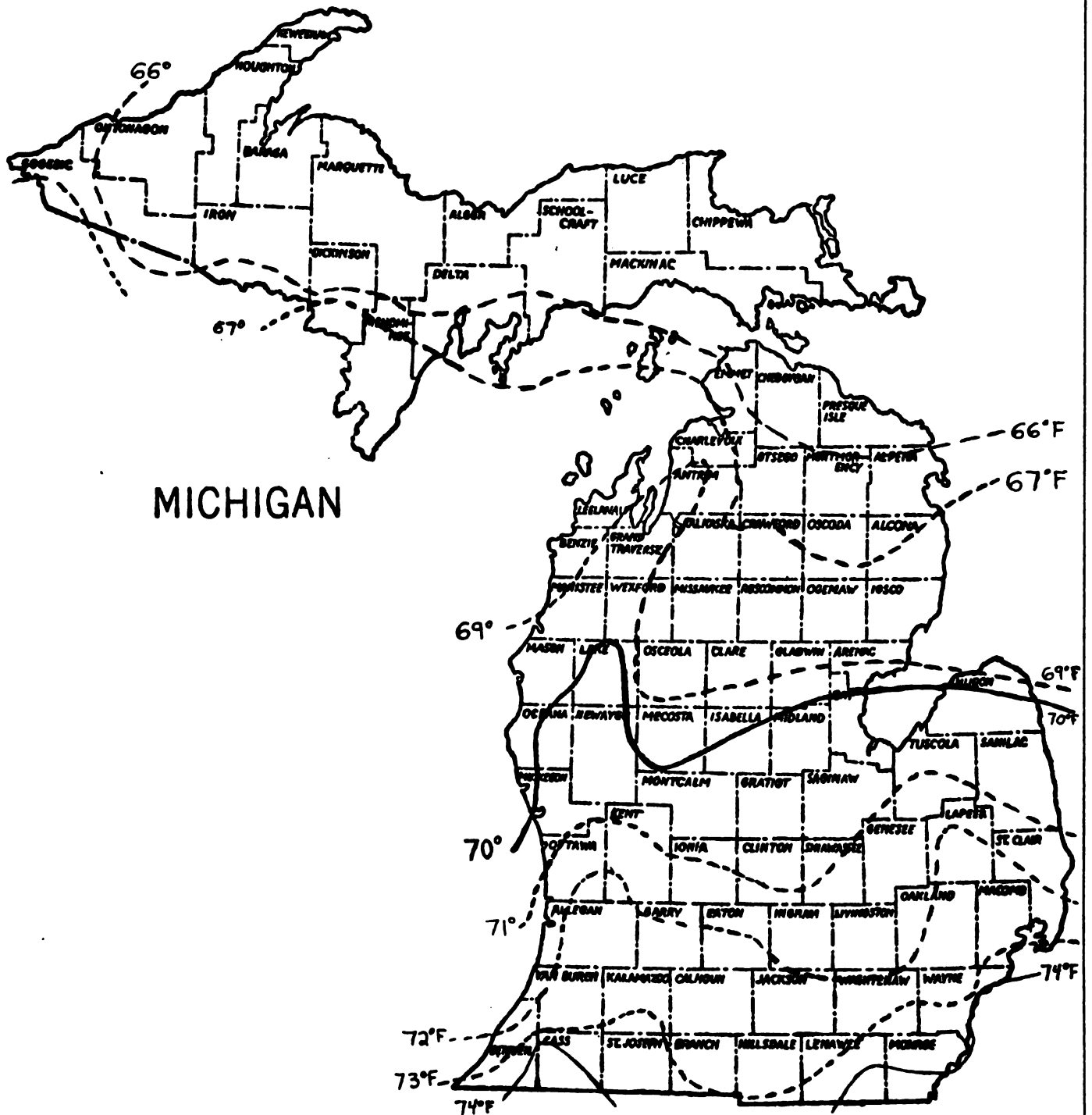


Figure 26. Average July isotherms, 1931-1960



Figure 28. Average date of last temperature of 32° F or lower



Figure 29. Present Michigan forests

the present forests of Michigan in dark shading. Figure 30 shows the terrain elevation in Michigan. No shading indicates an elevation under 800 feet above sea level. Light shading represents an elevation between 800 and 1000 feet above sea level. Dark shading indicates a terrain elevation above 1000 feet. Elevations above 1400 feet are indicated by horizontal lines within the dark areas.

DISCUSSION

The distribution of Michigan Bombinae appears to be related to several ecological factors. A few factors which are better known are rodent distribution and several climatic factors. These will be discussed for each species of Bombinae found in Michigan.

Bombus affinis has a unique distribution with limits at the southern border of the state and the straits area between the two peninsulas. The northern limit matches limits of Sciurus niger, Citellus tridecemlineatus, Glaucomys volans, Pitemys pinetorum and Peromyscus leucopus. B. affinis probably utilizes Citellus and Peromyscus nests. The nearest relative in Michigan to B. affinis is B. terricola. They compete in the northern part of the lower peninsula.

Bombus bimaculatus has a northern limit approximating that of B. affinis. The center of the range is south of Michigan. The mammals which have terminal ranges closely approximating the northern range limit of B. bimaculatus are the same as those listed for B. affinis. B. bimaculatus is a long tongue species related to B. vagans. It is one of the earliest species to appear. One stress period occurs in early spring. Several days of cold wet weather in early May could eliminate this species. In May of 1963, over four inches of rain fell in the upper lower peninsula. The average last day of temperatures of 32°F or lower (figure 28) is after May 20 in this area. Another stress period is mid-July when young queens and males emerge. Cold wet weather at this

period could weaken the colony. This kind of weather is unusual in northern Michigan in mid-July and is probably not as limiting as the May weather.

Bombus borealis is a northern species which is one of the latest species to emerge in the spring. In the southern third of the state, the species has been limited to elevations above 800 feet above sea level. It has not been found in extreme southwestern Michigan where average annual precipitation exceeds 35 inches annually.

Bombus fervidus, a long tongue, cosmopolitan species related to B. borealis, B. nevadensis and B. pennsylvanicus, has not been found in the western upper peninsula. The soils in this region are listed as non-limy and a range of elevations over 1400 feet separates this region from the rest of the state except along the northern boundary. This species is one of six species which have colonies maturing in late summer in Michigan.

Bombus frigidus, a short tongue northern species, was reported on Isle Royale and in a few scattered localities along the southern shore of Lake Superior in Michigan. This range boundary is near the boundaries of Rattus norvegicus, Mus musculus, Sciurus carolinensis, Microtus chrotorrhinus and Phenacomys intermedius.

Bombus griseocollis, an intermediate tongue southern species, has a range similar to B. bimaculatus. The colony develops more slowly than B. bimaculatus. Males occur in late July to early August. Known upper peninsula records

are from the shore of Lake Michigan.

Bombus impatiens, an intermediate tongue southern species, has a range similar to B. bimaculatus. Although the queens emerge as early as those of B. griseocollis, males appear later, from mid to late August.

Bombus nevadensis, a long tongue, large southern species has a northern boundary near the southern boundaries for Castor canadensis, Glaucomys sabrinus and Erethizon dorsatum (figure 25). This is near the 70°F July isotherm (figure 26) and the southern limit of extensive forests (figure 29). B. nevadensis occurs more frequently at elevations below 800 feet (figure 30) and is common in southwestern Michigan where precipitation exceeds 35 inches annually.

Bombus pennsylvanicus, a long tongue, large southern species, appears in mid to late May and males appear in late August. The range is very similar to B. nevadensis in Michigan.

Bombus perplexus, an intermediate tongue northern species, has a range similar to B. borealis. Males appear in early July. Although widely distributed, relatively few specimens of this species have been collected.

Bombus rufocinctus, a short tongue northern species, appears in late May. The range 30-60 years ago approximated B. borealis and B. perplexus. Recent records near the limit of the species are near (1) the limits of the rodents Castor canadensis and Glaucomys sabrinus (figure 25) (2) the 70°F July isotherm (figure 26) (3) the less than 30 inches of

annual precipitation line in the lower peninsula (figure 27) (4) the present extent of forests (figure 29) and (5) the over 800 feet terrain lines in southern Michigan (figure 30).

Bombus ternarius, a short tongue northern species, has a range similar to B. rufocinctus. It appears earlier in the spring and males appear earlier than in B. rufocinctus.

Bombus terricola, a short tongue northern species, has a range similar to B. rufocinctus but is much more common. The nearest relative is B. affinis.

Bombus vagans, an intermediate tongue cosmopolitan species, is found in all but 11 of the 83 counties. It is common throughout the state. Males occur in early July.

Psithyrus ashtoni is a northern species which has a distribution pattern similar to B. terricola with the exception of a few southwestern Michigan records. It is known to associate with B. affinis as well as B. terricola.

Psithyrus fernaldae is a northern species with a unique distribution pattern since all Michigan records so far are within 16 miles of the coast of one of the Great Lakes. It has a northern distribution and males appear in early to mid July. The ranges and dates of appearance of queens and males suggest that P. fernaldae may be associated with B. perplexus.

Psithyrus insularis is a northern species which is known to be associated with B. ternarius. Most specimens have been collected in northern Michigan. It was recently found in Kalamazoo County.

Psithyrus laboriosus is a southern species which is found throughout most of the state. Wisconsin and Keweenaw County records suggest it will eventually be collected in the remaining five western counties. It appears in early June and is known to be associated with B. vagans, B. impatiens and B. pennsylvanicus.

Psithyrus variabilis is a southern species which is known to be associated with B. pennsylvanicus. It appears in late June and males appear in late August. It has not yet been collected in Michigan but appears in two counties close to the border.

In summary, many factors, usually in combination, influence Bombinae distribution. Among the most significant are temperature, rainfall, vegetation, terrain elevation, host distribution in Psithyrus spp., rodent nest sites and predation. Future intensive studies of one or two species, such as B. pennsylvanicus and B. borealis would be very profitable in discovering more precisely the reasons behind the distribution of these species.

SUMMARY

More than 15,000 bumble bees were examined in order to determine ranges, variation and occurrence of mites associated with the 19 species of Bombinae which have been collected in Michigan or reported from counties in Indiana which border Michigan. Based upon the location of the center of the range, in relation to Michigan, nine species of Bombinae are noted to be northern species, three are cosmopolitan

species and seven are southern species. Rodent nests are frequently selected as nest sites and since rodents destroy Bombinae nests in early spring, the ranges of selected rodents were discussed. Similar patterns of both Bombinae and rodent distributions were noted. Finally, selected ecological factors which may influence Bombinae were presented. Temperature, rainfall, vegetation and host distribution for Psithyrus sp. are among the more significant of the factors considered.

NESTS OF MICHIGAN BOMBINAE

In order to understand relationships between mites and bumble bees, a knowledge of the nesting habits and life history of bumble bees is essential. The following section was planned to consider the life history of a Michigan bumble bee, presentation of nest data and a discussion of these data.

In Michigan, from mid-April to mid-June, Bombus spp. queens emerge from hibernation in soil or elsewhere and search for nest sites. Usually, but not always, the site is a former rodent nest. Competition for sites may be severe. Several dead queens have been found outside a new nest site (Frison 1928, Plath 1934). Once the nest site is selected, wax which is exuded between abdominal segments accumulates on the floor of the small cavity at the center of the nest site. This is formed into a wax thimble-sized structure known as a honey-pot. An egg cell may be constructed before the honey-pot. Usually, seven to eight eggs hatch in three to four days. At first the larvae feed on pollen in the closed egg cell.

In some species, the queen has been observed to open the cell and regurgitate into it. The larvae have been observed to feed upon this product. In other species, the larvae feed on pollen deposited directly into pockets at the sides of the egg cell. About a week after hatching, larvae spin cocoons and become pupae. The cocoons are incubated by the queen for about 11 days. During this time, additional egg cells are constructed at the side of the first clumps. The bees in cocoons immediately under the queen emerge first. The queen aids in cutting open the cell. In two or three days the worker begins foraging. Nests may contain as many as 500 to 1000 bees but in Michigan the largest number per nest collected thus far is 227. From early July to September, depending upon the species, males and young queens begin to emerge. After mating, young queens usually burrow into the ground near the site of the nest from which they originated. The winter is spent in hibernation. They emerge the following spring and the cycle is repeated. Inclement weather or disruption of the nest may cause variations from the pattern described above.

The twenty-seven nests which are tabulated in the appendix were all collected at night. Most of the records are for late species of bees since the majority of the nests were collected in September.

As the nest was jarred a few bees would exit. The bees were picked up one or two at a time and placed in a covered wide mouth gallon jar. Heavy gloves prevented injury to the

bees or the collector. A weak light from a covered flash light provided visibility. Under these conditions, the bees rarely flew. A small amount of tissue paper on the bottom kept the jar relatively dry. The bees were unable to crawl up the smooth sides of the jar and did not attempt to fly out when the lid was removed. When no more buzzing was heard in the nest, the nest was carefully opened and examined for any remaining bees. The nest was then transferred to a second gallon jar, covered and transported to the laboratory.

In six cases, the nest and bees were transferred to boxes and maintained on sugar water for periods up to 50 days before removing bees and placing the nest in a modified Berlese funnel. The Berlese apparatus consisted of a covered sheet metal funnel. An opening in the top of the cover admitted a cord for a 40 watt light bulb. A screen in the funnel held the nest and permitted arthropods to move through the screen away from the heat and desiccation. Jars of 70% alcohol were taped to the bottom of the funnel. In five cases that are noted, modifications of this procedure were used. In one instance, an open glass funnel was used. In three cases, the light and cord were removed and cotton was placed in the opening at the top of the funnel. Chloropicrin (tear gas) was dropped on the cotton to drive arthropods into the alcohol. In one case a dish of alcohol and glycerine was placed below a nest in a field.

Two of the nests were collected by an undergraduate student and placed in the center of a field. The nests were in a declining state when mite samples were collected. Very few bees remained in the nest.

Most of the nests were placed within the modified Berlese apparatus within a few hours after collection. Most of the bees were killed with carbon tetrachloride, pinned, labeled and stored in separate boxes to be examined for mites in the following few days. Some of the killed bees were stored in 70% alcohol. Others were refrigerated or frozen in individual vials. In some instances living bees were stored in vials and boxes in the refrigerator and freezer after being anesthetized with ether and examined for mites.

After periods in the Berlese funnel varying from nine hours to a few days depending upon the size and construction of the nest, the nests were stored in plastic containers. Later, each nest was examined with forceps for bones, seeds or other clues which might indicate former inhabitants. The construction materials were noted at this time.

Some of the nests were used in unsuccessful attempts to initiate new colonies in the spring of 1964. About half of the nests are stored in insect trays at the Entomology Museum at Michigan State University.

DISCUSSION

All of the nests described in detail in the appendix were collected in the southern counties of Michigan. The nests were all mature or declining. No early nests were examined. The dates of collection ranged from 7 July to 12 September.

More than half of the nests may be former rodent nests, based upon the location of the nest and presence of seeds, hair or skeletal remains. Two nests had identifiable skeletal remains of Peromyscus sp. Most of the nests were removed from a location near buildings. This is due to the fact that reports of nests by man were the main source of information concerning locations of nests.

Arthropods associated with Bombinae were found in all of the twenty-seven nests obtained. Acarina were common to twenty-six of the twenty-seven nests. Nest contents are summarized in table 1. The number of nests in which the animals were found follows the name of the group.

No measurements of environmental conditions within the nest were taken in this study. Based upon the variety of locations of the nests and the difference in numbers of animals in the nests, the internal microenvironments may be quite different from one nest to another. Likewise, the various construction materials have quite different insulating properties. A nest composed of leaves and situated two feet underground may have an internal environment quite

unlike that of a nest of macerated twine on a shelf in a garage or a nest of cotton inside a washing machine in a field.

Table 1. Invertebrates found in 27 Bombinae nests

Invertebrate taxa	Number of nests	Invertebrate taxa	Number of nests
Acarina	26	Siphonaptera	4
Coleoptera	18	Chilopoda	3
Lepidoptera	18	Orthoptera	3
Collembola	12	Araneae	2
Diptera	10	Diplopoda	2
Hymenoptera	10	Annelida	1
Psocoptera	9	Mollusca	1
Isopoda	4	Nematoda	1
Pseudoscorpiones	4		

Studies of rodent nests and Bombinae nests indicate that the microenvironment inside the nest differs considerably from the surrounding environment. Hasselrot (1960) has experimented with the ranges of temperatures and relative humidities of bumble bee nests in Sweden. He found that relative humidity remained between 60% - 70% throughout the season. He also found that temperature variations were more pronounced in nests early in the season than in mature nests. The temperature of an occupied nest was never lower than the outside temperature.

Future comparative studies of nests occupied by rodents, nests occupied by Bombinae and unoccupied nests may prove to

be very interesting in terms of the ecology of the arthropods associated with these two groups of animals.

In summary, Acarina were common to 26 of 27 nests of Bombinae obtained. Coleoptera and Lepidoptera were found in 18 nests. Six other orders of insects were obtained as well as Arachnida, Crustacea, Chilopoda, Diplopoda, Annelida, Mollusca and Nematoda. Most of the nests may have been previously occupied by rodents.

PART II

ACARINA ASSOCIATED WITH MICHIGAN BOMBINAE

Acarina have been observed on American Bombinae and in their nests for over 100 years (Putnam 1864). Some of the first adequate descriptions of mites on bumblebees began in Europe with Canestrini in the late 1800's and were followed in the early 1900's by Oudemans and Berlese. Zakhvatkin (1941) and Vitzthum (1930) investigated Bombinae mites in the 1930's. They were followed by Stammer and Postner in the 1940's and 1950's. No work such as was attempted by Vitzthum, Stammer and Postner has been accomplished in the Americas although reports of mites associated with Bombinae are fairly common. Banks, Ewing and Frison are responsible for some of the early reports.

Plath (1934) reported mites in bumble bee nests in the Eastern United States. E. A. Cross in the 1950's found mites on pinned Bombus sp. in the collection at the University of Kansas. Medler found mites in the nest of B. huntii in New Mexico and Hunter has described mites from bumble bees in the University of Georgia collection. Lindquist and Thorp observed mites on bumble bees collected in California. Since 1962, several thousand mites have been taken from pinned and freshly caught bumble bees and from bumble bee nests in the state of Michigan. Thus, mites are known to be associated with bumble bees throughout the United States.

Reports of mites associated with Bombinae are not common outside of the United States and Europe. Bumble bees occur

in Africa north of the Sahara, in North and South America and in Asia. They have been introduced in Australia and New Zealand. Zakhvatkin (1941) reports three commensal mites associated with Bombinae in Russia. Cumber (1949) mentioned an internal mite in Bombus lucorum near London, England. Stammer (1951) described it as Bombacarus buchneri and found it in several Bombinae in Germany. Postner (1951) reported three mite species in abundance in bumble bee nests in Germany. Skou, Holm and Haas (1963) reported three species of mites associated with Bombinae in Denmark. Kielczewski in an unpublished abstract from the First International Institute of Acarology reported mites from nests of Bombinae in Poland. As the Asian and South American species are studied more intensively, mites will probably be found to be associated with bumble bees throughout the world.

The scope of this study is to deal with the distribution, associations and descriptions of mites found in or on Michigan bumble bees or in their nests.

METHODS AND MATERIALS

Few descriptions of techniques dealing with mites associated with hymenoptera were found in the literature. Several techniques were used initially. In general, the following objectives were considered desirable. (1) The collecting techniques must be efficient to permit rapid collecting and handling of large numbers of bees. (2) Mite transfer from bee to bee and loss of mites from bees must be minimal to give an accurate concept of associations and incidences of

occurrence of mites. (3) The procedure of examination of bees must be standardized to be certain each species of bee and each locality collected is uniformly treated. (4) All vials, bees and slides must be labeled with a minimum of date, locality and sample number for future reference. (5) All specimens must be stored in a manner that will insure continuing preservation of the data. (6) All bumble bee nests should be examined in a consistent manner.

It is not always possible to meet the objectives listed above. The following paragraphs describe the several procedures attempted and the ones presently used.

COLLECTION PROCEDURE

Although museum specimens were examined and utilized, many of the bumble bees were caught and examined immediately upon return to the laboratory. Bees were caught at flower with an insect net, transferred to a killing jar and pinned and labeled in the laboratory. The net used throughout this study was rarely used for species other than Bombinae. If a considerable number were caught at a considerable distance from the laboratory, several days elapsed before examining for mites. Museum specimens that were dried for several years were placed in a humidifying jar before being examined.

Several killing agents, collecting techniques and preservation techniques were employed. Most of the specimens collected in 1963 and 1964 were killed with cyanide. Chloroform was used to kill the bees taken from one nest in 1963. The cyanide in jars tends to dissipate and become a less

effective killing agent after a few weeks of continuous use of the jar. Most of the specimens in 1965 and 1966 were killed with carbon tetrachloride although ethyl acetate was used for several samples. Carbon tetrachloride is now used exclusively. It is very easy to handle and is less volatile than ether or chloroform. An extra bottle may be transported into the field. It kills rapidly and does not dissolve the plastic in the lid of some jars as ethyl acetate does. On one trip in 1964, cigar smoke was used to asphyxiate bees when all killing jars were full.

Some bees were captured by placing a small screw top vial over them while on the flower. While this is not always effective, bees trapped in this manner are least likely to be contaminated with mites that may have been knocked off other bees in a common collecting net. Most of the bees collected were collected in a common net, transferred to a killing jar for a few minutes and then removed to a 1" x 2 $\frac{1}{4}$ " screw top vial. Upon return to the laboratory, most of the bottles were emptied and examined for mites. The bees were pinned, labeled and examined for mites. In some instances the bottles containing bees were refrigerated temporarily or frozen for extended periods of time. In a few instances bottles containing bees were filled with 70% alcohol.

The plastic suction collecting device utilized by some entomologists at Cornell University was not evaluated but looks promising for future work in this area.

PROCEDURE FOR BEE EXAMINATION

When examinations of bees began early in 1963, as much as 30 minutes was utilized per bee. As handling techniques became more familiar, the time spent per bee gradually decreased. It now takes from one to two minutes depending upon the condition of the specimen. A 10X and 30X binocular dissecting microscope is utilized. In 1965, nearly all the bees collected were examined within two hours after capture. It is much easier to move the parts if freshly caught bees are examined. In 1963, I noted that mites found on bees killed in one weak cyanide dilling jar were still alive and a few were noted crawling down the insect pin. Bee specimens left over four days are usually not satisfactory for examination for internal mites although these mites have been identified in specimens pinned for a month. These soft bodied mites are barely recognizable after this period of time.

The dorsal aspect of the bee is examined first. The bee is held in one hand while manipulating the hairs of the thorax and abdomen with an insect minuten at the end of a matchstick. The abdomen is depressed and the area between the thorax and abdomen is examined. Grooves between the scutellum and propodium are probed and the area between the head and thorax is examined.

An examination of the front and side of the head is made. The region between the head and neck as well as the mouth parts on the ventral aspect of the head are inspected. Next, the area near the pronotal spiracular lobe and the various inter-

segmental grooves are probed. The tegulae and the wings are examined. The area of the propodeal spiracle is probed. An examination around the coxae and thoracic sternites follows. Finally, the abdominal sternites and lateral aspect of the abdomen are examined.

Throughout the 1965 collecting season, freshly caught bees were examined for internal mites as well as external mites. The first internal mites were found and techniques were developed in 1964. After the routine examination above, the bee is grasped between abdominal sternite one and two with fine forceps. With a second pair of fine forceps, an incision is made between the two sternites and enlarged by grasping abdominal sternite one and pulling sternites one and two apart. This reveals the ventral aspect of the crop (honey sac) and the anterior portions of the paired air sacs. If the crop is distended with nectar, it may be removed by grasping the narrow anterior portion and pulling it. The crop separates from the remainder of the digestive tract at the junction of the ventriculus and proventriculus in most cases. If care is taken the crop will not burst. If it does, tissue paper is used to absorb the nectar. If the nectar is spilled into the air sacs, which are examined next, it is very difficult to find and remove internal mites. The air sacs are punctured with the sharp tips of the forceps. Releasing the closed forceps widens the initial opening and widens the posterior abdominal air sacs as internal inspection continues. After inspection and removal of mites to slides

or to 70% alcohol, the abdomen falls back to its normal position as the dorsal aspect is still continuously connected. The bee may be pinned and labeled before or after examination. In larger bees, the weight of the pin is helpful in holding open the inspection cavity.

BEE LABELING AND STORAGE PROCEDURE

In most instances, bees were individually labeled immediately upon return from the field. All of the bees were re-examined for determination of the bee species and identification labels were affixed in 1966. Sufficient supplies of moth crystals (paradichlorobenzene) were maintained in each box to discourage dermestid beetles and other pests. Unfortunately, the nests were not all sufficiently protected after examination and are now contaminated with dermestid remains and probably other species. Most of the nests are now preserved in insect trays and are satisfactory for possible studies of nest construction but are not suitable for micro-examination for mites or other arthropods which may have been a part of the nest fauna at the time the nest was inhabited by bees.

FOR REMOVAL OF ACARINA FROM BOMBINAE

The method of mite extraction from bee nests by utilization of a funnel apparatus has been described earlier in this report and will not be repeated. The chloropicrin method is very effective. It is a little difficult to use unless a good breeze is blowing outside or an adequate ventilation hood is present indoors as chloropicrin is a lacrymal

agent.

The mites are removed from the bees with an insect minuten placed in the end of a matchstick. Internal mites are sometimes removed by taking out a piece of the air sac wall. No problem is encountered with fresh specimens. The mite is placed ventral aspect up on a drop of Hoyer's mounting medium on a 25mm x 75mm slide, positioned and air bubbles are removed before placing an 8 - 12mm cover slip over the mite. The slide is placed in a drying oven at approximately 45°C until a hard surface is formed at the edge of the cover slip. After cooling, a ring of laquer is placed around the edge of the cover slip to help seal the surface of the mounting medium. The mounting medium is 50 ml. distilled water, 200 grams chloral hydrate, 30 grams gum arabic and 4 ml. glycerine.

PROCEDURE FOR PRESERVATION AND LABELING OF ACARINA

Mite specimens removed from dry bees are difficult to mount properly as air bubbles are trapped within the mite and the legs break easily. If the mites are stored in 70% alcohol for a few weeks, they are usually quite pliable and the air bubbles are replaced with alcohol. An eye dropper is used to transfer mites from vial to the slide. After the alcohol partially evaporates, a drop of Hoyer's is placed on the mite and the procedure described above is followed. In a few instances, heavily sclerotized mites are placed in 80% lactic acid until cleared sufficiently or are stored in Hoyer's mounting medium for a day or two at 50°C before mounting on

a slide. Mites stored in alcohol are inside cottenstoppered, 9 x 30mm, $\frac{1}{4}$ dram, short shell vials which in turn are inside neoprene-stoppered, 17 x 60mm, 2 dram, patent lip vials. Labels which contain the same information that is found on the insect pin are in each vial.

After several labeling schemes were investigated the following one is now consistantly used. The date is given first followed by a sequence number. If 10 bumble bees were collected on July 10, 1963, the labels would appear as 10 July 1963-1, 10 July 1963-2 and so on through 10 July 1963-10. In the past two years, only bees with mites were given sequence numbers. The sequence number appears in the vials, on the slides and on the bees. It is a simple matter to find a specimen. The next information is the state and county of collection. Below this appears the tier, range and section or other more specific locality information. The last information is the collector's name. Most of the vials do not contain the species of Bombinae from which the mites were obtained as the species were determined after the vials were prepared. Nearly all of the slides have the genus and species of Bombus sp. as well as other collection information on the left label. The right label on the side contains information on the identity of the mite. The specimens stored in alcohol are available through Dr. Roland Fischer, Director of the Museum of Entomology, Michigan State University, East Lansing, Michigan. Most of the slide collection is retained by R. W. Husband for future work in this area. Information

on disposition of type specimens is found after the description of the species.

IDENTIFICATION OF ACARINA

The literature upon which some identifications were based appears in the discussion of the various groups. The following authorities contributed to determinations varying from species to families;

- E. W. Baker - Acaridei (genera, species)
- J. Camin - Uropodid and other Mesostigmata (genera)
- E. A. Cross - Scutacaridae (genera, species)
- P. E. Hunter - Pneumolaelaps (species)
- D. Johnson - Oribatei
- E. Lindquist - Proctolaelaps (species Haemolaelaps,
Cosmolaelaps (genera)

Unpublished keys provided as a part of a summer session of the Institute of Acarology at Ohio State University and Guide to the Families of Mites (Baker et al., 1958) were also used.

A phase contrast AO microstar microscope was used for identifications, drawings and photographs. Low power photography of bees with mites was accomplished by a Nikkormat FT camera with assistance from Mr. Wayne Lancaster.

THE BIOLOGY, DISTRIBUTION AND NEW COMBINATION OF
Locustacarus (Bombacarus) buchneri (Stammer) 1951

The generic taxon Bombacarus was erected as a monotypic genus (Podapolipodidae) by Stammer in 1951 with Bombacarus buchneri as the type species. The first two internal mite species of this family were described from Locustidae by Ewing. Locustacarus trachealis Ewing (1924) was described from trachea of Hippicus apiculatus (Harris) and Arphia carinata; Locustacarus locustae Ewing (1932) from the African Locusta migratorioides. Stammer found Bombacarus buchneri in several species of European bumble bees in Germany. It has also been found in England (Cumber 1949), Austria (Postner 1952), Denmark (Skou, Holm and Haas 1963) and Sweden (Hasselrot 1960). A search of the literature has revealed three species of internal mites in this family and several external species associated with beetles and grasshoppers.

Stammer characterizes the genus as follows: "Both sexes with three pairs of legs without pseudostigmatic organs. All tarsi with two claws and a large empodium somewhat narrowed at the base. A large median pair of setae on the posterior margin of the propodosoma. Oviparous. The adults develop directly from the eggs. The genus is near Locustacarus sp. It differs in the markedly varying physiology and the striking median pair of setae on the propodosoma."

A review of specimens of Locustacarus spp. and Ewing's description of the genus has been made. Both Locustacarus sp. and Bombacarus sp. are tracheal parasites of insects. The

body chaetotaxy differs somewhat in position and relative length of setae but not in number of setae from Locustacarus trachealis Ewing (1924) and Locustacarus locustae Ewing (1932). The last pair of propodosomal setae are longer than the other propodosomal setae in both Locustacarus sp. and Bombacarus sp. On the basis of similar but not identical chaetotaxy and similar physiology, Bombacarus is considered to be a synonym of Locustacarus.

Differences between the drawings of Locustacarus buchneri (Stammer) and specimens of Michigan L. buchneri have been noted. European specimens of this species have not yet been examined. On the basis of many observations and a lengthy discussion with Dr. Edward Baker of the U. S. Department of Agriculture, a description of this species based on Michigan L. buchneri is offered.

Locustacarus buchneri (Stammer) 1951, New Combination

Newly developed female (figures 31 and 32). Body oval, length 181 μ , greatest diameter 107 μ , tail setae 122 μ .

Gnathosoma follows Stammer's description for Locustacarus buchneri.

Dorsal aspect (figure 31): The long pair of prodosomal setae are approximately 3/4 of the body length as given for L. buchneri. The opisthosoma differs in that the small pair of sub-median setae are found on a nearly square sclerite. The long pair of tail setae are about the same length as the setae in L. buchneri.

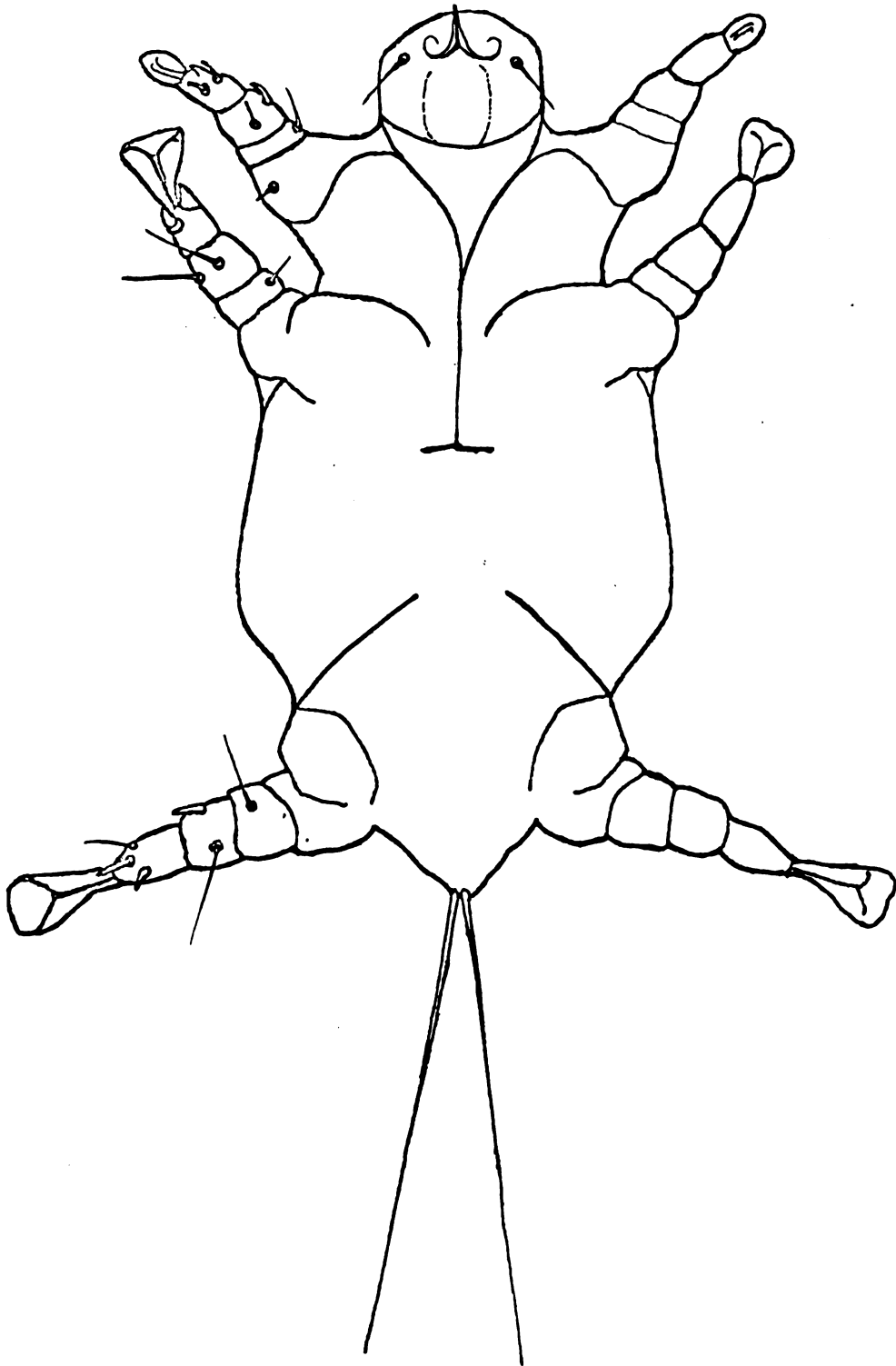


Figure 32. Locustacarus buchneri, ventral aspect, young female

Ventral aspect (figure 32): The three pair of sternal grooves are the same as L. buchneri.

Appendages: The three pair of legs are similar to L. buchneri but differ in chaetotaxy (table 2). The underlined numbers represent numbers which differ from numbers given by Stammer for this species.

Table 2. Locustacarus buchneri, female, leg chaetotaxy

	Trochanter	Femur	Genu	Tibia	Tarsus	
Leg 1	0	2	1	<u>2</u> (1)	<u>2</u> (1)	<u>3</u> sensory setae
Leg 2	0	0	1	<u>3</u> (<u>1</u>)	2(2)	<u>1</u> sensory seta
Leg 3	0	0	1	3(1)	2(<u>1</u>)	<u>3</u> sensory setae

All tarsi have two claws and an empodium. The claws and empodium are reduced on tarsus 1. As in L. buchneri, the ambulacral apparatus of the first tarsus is scarcely narrowed. The ambulacral apparatus of tarsi two and three are well developed and markedly narrowed proximally.

Developing females: The developing female resembles L. buchneri. The eggs are oval 177-191 μ long and 117-129 μ wide. The eggs are thus somewhat longer and the range in width is less than that described for L. buchneri.

Males (figures 33 and 34): Slightly smaller than the young females. Length 145 -150 μ , width 99-102 μ .

Gnathosoma; Chelicera as described by Stammer. Palpi with an empodium-like lateral membranous projection with three small stiff chitinous supports.

Dorsal aspect (figure 33): Three pair of setae on the anterior margin of the propodosomal shield. Metapodosoma

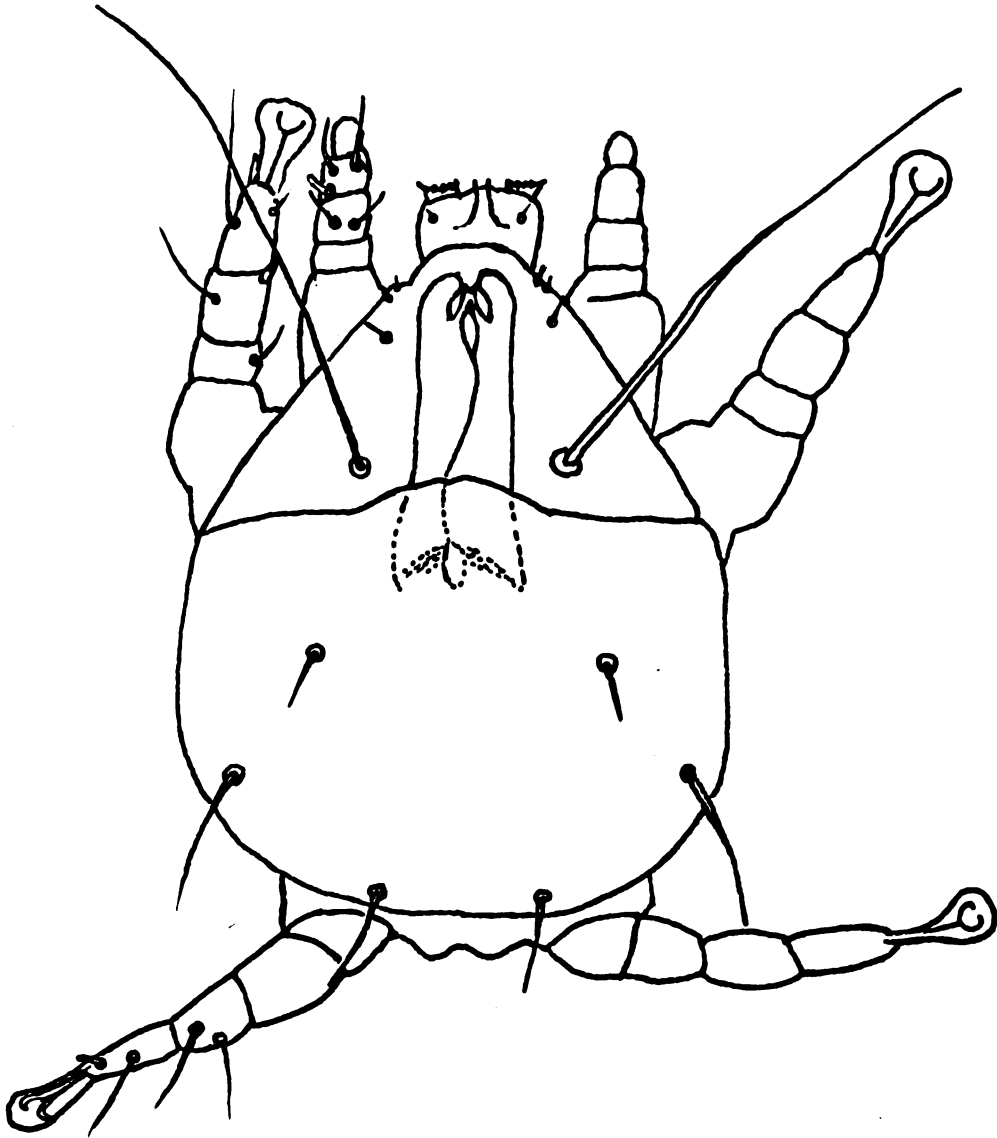


Figure 33. Locustacarus buchneri, dorsal aspect, male

nearly rectangular, elevated and folded posteriorly. Metapodosomal setae more developed than in the female. Opisthosoma cone-shaped without the long paired setae that appear in the female.

The penis originates at the anterior margin of the metapodosoma and closely resembles European Locustacarus buchneri and other Locustacarus spp.

Ventral aspect (figure 34): The ventral aspect differs little from Locustacarus buchneri.

Appendages: The leg chaetotaxy differs from the female. The underlined numbers represent differences from numbers given by Stammer for the male (table 3).

Table 3. Locustacarus buchneri, male, leg chaetotaxy

	Trochanter	Femur	Genu	Tibia	Tarsus	
Leg 1	0	4	1	<u>4</u> (1)	<u>3</u> (1)	<u>2</u> sensory setae
Leg 2	0	0	1	3(1)	<u>2</u> (<u>1</u>)	<u>2</u> sensory setae
Leg 3	0	0	1	3(1)	<u>2</u> (<u>1</u>)	<u>3</u> sensory setae

The tarsal spines, setae and sensory setae differ markedly from those given for L. buchneri.

Occurrence: In the airsacs of Bombus bimaculatus in Kansas, Missouri and Michigan, in one male Psithyrus laboriosus and one male Bombus vagans. Sinha (personal communication) reports Locustacarus sp. from Bombus terricola in Canada. In several European Bombinae.

Locustacarus buchneri develops directly from egg to adult. The mites are nearly mature when the eggs leave the female. Judging from the positions of mites upon removal

from the bee air sacs, copulation takes place very soon after the mites break out of the eggs. Stammer (1951) observed that the mature females were usually found to contain 2-5 large eggs although as many as 50-60 may be found stuck together around the female.

Most of the observations made of Locustacarus buchneri in Michigan Bombinae agree with Stammer's detailed description of the biology of this species in Germany. The following differences were noted. Whereas L. buchneri in Germany was observed to be less numerous in the short lived species Bombus pratorum than in long lived species, L. buchneri in Michigan seems to be primarily associated with the short lived species Bombus bimaculatus. Throughout 1965, many species were methodically examined for internal mites. Internal mites were very common in Bombus bimaculatus in Michigan and Missouri and had been found by D. Dias in Kansas in 1960. However, only one male Psithyrus sp. and one Bombus vagans male had internal mites. Sinha has found Locustacarus sp. in Bombus terricola in Canada but I am not aware of the complete details of this record as Sinha is in Japan while his records are in Canada.

L. buchneri was found in bees from two nests of Bombus bimaculatus. On 4 August 1965, a declining nest was found at the W. K. Kellogg Biological Station in Kalamazoo County, Michigan. The few remaining worker and male bees were observed in place for several days. On 5 August, two bees were observed crawling on top of the nest. Large mesostigmatid

mites were crawling on both bees. One bee was removed with forceps and placed in a covered Petri dish. The bee was not very active and died the following day. About an hour after it died, two living young female Locustacarus buchneri were noted on the posterior lateral aspect of the thorax and a third on the lateral margin of abdominal tergite I. They were removed and placed on slides. A fourth mite was removed from the left thorax and a fifth and sixth were found on the glass near the bee. Several hours later one had died. The other was moving slowly. Both were put on slides. No other L. buchneri were noted in the dish or on the bee. The bee was dissected and living males, young females and a mature female were removed from the abdominal air sacs and placed on slides. The air sacs were dark brown as described by Stammer. This is the first recorded instance of this mite outside the air sacs and trachea.

A second bee was removed on 6 August and died on 9 August. No L. buchneri were observed on the bee but three dead ones were found on the glass near the bee on 9 August. This bee had many acarid hypopi on both corbicula. On 9 August, no mites were on the corbicula. Hypopi were crawling on the bee and dish. On 11 August mesostigmatid mites and acarid hypopi were found externally and male and female L. buchneri were found internally.

A third bee was picked up with forceps. It had diarrhea and was killed and examined. Several male and female mites were removed from the abdominal air sacs. As in the other

cases, the airsacs were dark brown. This is the first time that a bee was noted to have diarrhea and gives further evidence to the claim by Skou, Holm and Haas (1963) that the consequences of infestation with L. buchneri can be serious.

The nest was placed in an open glass funnel on 11 August and no internal mites were observed in the nest or collected in the alcohol below.

A second nest was of Bombus bimaculatus and obtained on 7 July 1966. The nest was at its peak of activity. Males and newly emerged queens were present. This nest has been described earlier in this report. Males, queens and workers had internal mites. One of two pupal queens had mites in an abdominal air sac. This is the first record of an internal mite in a pupa and suggests that the young female mites may enter the cells of larvae as they are fed by workers. Hobbs (personal communication) states that openings are made in cells by worker bees in feeding larvae and are open long enough for mites to enter the cell. Medler (1959) noted other kinds of mites are also found occasionally in closed cells. Over half (60.7%) of the worker bees had internal mites and 54.8% of the males had L. buchneri in the abdominal air sacs. Forty-six percent (13 of 28) of the queens had internal mites.

In summary, Locustacarus (Bombacarus) buchneri (Stammer), new combination, is justified on the basis of similar morphology and physiology. L. buchneri is redescribed with changes in leg chaetotaxy and the addition of an opisthosomal

plate. Living female L. buchneri were noted outside of a Bombus bimaculatus worker and inside a pupal queen.

RELATIVE ABUNDANCE OF MITE-INFESTED BOMBINAE

The relative abundance of Bombinae with mites has been recorded for a few European species. Stammer (1951) reported on Locustacarus buchneri (Stammer) in Bombinae in Germany. He found this mite in 12 species of Bombinae. The incidences of infestation were from less than 1% to 38% for the various species. Stammer states that infestation with this species is probably not significant as numbers of mites per bee are usually low.

Skou, Holm and Haas (1953) report Parasitus fucorum de Geer, Kuzinia (Tyrophagus) laevis Dujardin and Locustacarus buchneri Stammer in Bombus spp. in Denmark and state that the former two are important disease vectors in Bombus spp. They found a Bombus sp. queen so weak that she ceased nesting activity. Dissection revealed a large number of L. buchneri and the insides "almost entirely wasted away".

Loomis (1956) has studied the relative abundance of chigger larvae in Eastern Kansas during various months and a few other studies of vertebrate mites of this type are in the literature. However, studies of relative abundance of mites of hymenoptera are not common. A search of the literature has revealed no study which gives the relative numbers of Bombinae with mites throughout the year.

Between 1963 and 1966, several thousand pinned and freshly caught bees were examined for mites by methods

described previously. Records were not compiled for all of the museum specimens examined nor were all daily collections recorded. However, detailed records from 27 April 1963 to 24 October 1963 and supplemental records to 10 September 1966 include 3,477 Bombinae collected throughout the state of Michigan (Table 4). The following observations are based upon this sample. The mites are lumped together in this study to give an *estimate* of the total number of bees with mites. By far the most common mite is the deutonymph of Kuzinia laevis (Dujardin). The various other mites found will be discussed later. The figures in tables 4, 5 and 6 are rounded to the nearest whole percent.

Table 4. The seasonal occurrence of Acarina on Michigan

Bombinae (Numbers in parentheses indicate nest data)

Months 1963-66	No. of Bombinae With Mites	Total Number of Bombinae	% of Bombinae With Mites
April	7	7	100%
May	196	401	49%
June	41	125	33%
July	151 (72)	563 (99)	27% (73%)
August	204 (7)	886 (133)	23% (05%)
September	209 (196)	1468 (1427)	14% (14%)
October	20	27	74%
TOTAL	828 (275)	3477 (1659)	24% (17%)

The figures in table 4 include bees taken from nests at night. It is possible that mites may be found more or less frequently on nest bees than on bees taken at flower.

The figures in parentheses indicate that considerable differences may occur between the number of bees with mites from flowers and those from nests. One factor which might bias the results is interference with nest activity by man. One nest was doused with gasoline the day before it was collected. Another was in a ball of twine which may have been treated with fungicide and a third nest may have been sprayed with insecticide as the property owner was attempting to reclaim the dog house in which the nest was located. No mites were found on the bees in these nests and very few mites were retrieved from the nests.

The data in table 1 tend to suggest that the highest overall incidence of mites on bees is in April, May and October. Seven queens form the May sample and 27 bees constitute the October sample. Two queens collected in logs and 18 males collected at flower in October had mites.

Thirteen of forty-one bees (32%) collected at flower in September support the possibility of an increase in number of mite-infested bees outside the nest in September. This figure is lower in table 1 by the large number of nest bees without mites. The reduction in numbers of nest bees with mites in September may be a natural tendency but this is doubtful. A more detailed analysis of two nests which were known to be relatively undisturbed will be presented later in this report to support this conclusion.

The overall tendencies for occurrences of mites on Michigan Bombinae is highest in the spring and late fall and

lowest in July, August and September.

The frequency of mite-infested bees collected at flower in the lower peninsula of Michigan was compared to the number of bees with mites in the upper peninsula during May and August of 1964 and 1965 (table 5).

Table 5. Frequency of mite-infested Bombinae collected at flower in 1964 and 1965

Month	Area of Collection	No. of Bombinae With Mites	Total No. of Bombinae	% Bombinae With Mites
May	Lower Peninsula	77	165	47%
	Upper Peninsula	119	236	51%
August	Lower Peninsula	136	546	25%
	Upper Peninsula	61	207	29%

Slight differences occurred in relative abundance of Bombinae with mites in broad areas of the state during the period covered in this study.

The number of Psithyrus spp. which had mites compared to the number of mite-infested Bombus spp. appear to be more significant. In five days of collecting from different areas of Michigan's upper peninsula, 54 of 74 Psithyrus spp. collected had mites (table 6). The number of Bombus spp collected the same day are in parentheses.

The large numbers of Psithyrus spp. collected on May 31 were from seven sites in three counties and could not have come from one nest area. The remaining seven specimens were collected from widely separated areas but do not constitute a sufficient sample. However, the trend for a greater

infestation of upper peninsula Psithyrus spp. is supported by these data.

Table 6. Frequency of upper peninsula, mite-infested Psithyrus spp.

	No. of Bombinae With Mites	Total No. of Bombinae	% Bombinae With Mites
29 May <u>Psithyrus</u> spp.	2 (7)	2 (27)	100% (26%)
30 May <u>Psithyrus</u> spp.	1 (36)	1 (64)	100% (56%)
31 May <u>Psithyrus</u> spp.	47 (53)	66 (99)	71% (54%)
25 Aug. <u>Psithyrus</u> spp.	2 (8)	3 (47)	67% (17%)
28 Aug. <u>Psithyrus</u> spp.	2 (17)	2 (42)	100% (40%)

In summary, the relative numbers of Bombinae with mites is highest in April and steadily decreases until August. The relative numbers with mites then increase until October. Relative abundance of Bombinae with mites throughout the state appear to be nearly the same if the records of the same month are compared. The relative numbers of Psithyrus spp. with mites was higher than Bombus spp. collected on the same days.

THE RELATIVE ABUNDANCE OF MITE-INFESTED
BOMBINAE IN TWO SELECTED NESTS

Two nests of the 27 nests examined were selected for analysis as both were relatively undisturbed. The nest of Bombus bimaculatus reaches a climax with the production of males in early July in southern Michigan. The nest of Bombus pennsylvanicus reaches a climax with the production of males in late August. Both nests were collected near the climax of the nest activity.

The first nest presented is that of Bombus pennsylvanicus collected on 5 September 1963. It was collected in Kalamazoo County, T35, R11W, S26, from the ground underneath a pile of boards. It was composed of leaf litter and a small amount of glass wool. The Berlese sample included Araneae, Pseudoscorpiones, Chilopoda, Acarina, Isopoda, Collembola, Siphonoptera, Diptera, Coleoptera, Lepidoptera and Hymenoptera.

Thirty of 31 (97%) males, 18 of 21 (86%) queens and 49 of 101 (49%) workers had mites on them. The total number of bees with mites is 97 of 170 (57%) bees. The numbers of mites which occurred on these bees will be covered in the next section of this report. All of the mites collected from the Berlese sample were not separated from the debris. Representative mites were selected and put on slides. The remaining mites cover a volume approximately 50mm in diameter to a depth of 2 mm.

The second nest is that of Bombus bimaculatus collected 7 July 1966 in Lenawee County T6S, R3E, S34. It was located

under a cement slab porch. Very little of the outer nest material was recovered as the nest was difficult to reach. Twentyseven of 28 queens, 10 of 11 males and 34 of 56 workers had mites on them (table 7).

Table 7. Incidence of mite-infested Bombus bimaculatus

	Queens	Workers	Males	Total
Acarid hypopi only	14	0	4	18
Acarid hypopi and				
internal mites	12	0	3	15
Internal mites only	2 (1 pupa)	34	3	39
*Internal, Acarid				
and mesostigmatid	3	0	0	3
No mites	1 (pupa)	21	1	23

*also tabulated with acarid hypopi and internal mites.

Of the 95 bees, 72 (76%) had mites. The incidence of infestation was: internal mites - 57%, acarid hypopi - 35% and mesostigmatid - 3%.

In this particular nest, it is interesting to note that all but three (including 2 pupae) queen bees had acarid hypopi. Seven of the 11 males had acarid hypopi. Most of the males and queens appeared to have recently emerged. Some had only pollen in the crop. It is possible that acarid deutonymphs are attracted to newly emerged bees in preference to the older workers.

Nest bees from relatively undisturbed nests had a much higher percent of infestation than the monthly average for all Bombinae which was presented in the previous section.

Part of this may be due to the time of collection. However, workers had a much lower rate of infestation than either males or queens.

In summary, nest bees, particularly queens and males, have a higher percent of infestation than bees collected at flower in the same months. Acarid hypopi may be attracted to newly emerged bees in preference to older workers.

POSITION AND NUMBERS OF MITES ON VARIOUS
ANATOMICAL PARTS OF MICHIGAN BOMBINAE

Zakhvatkin (1941) states that large numbers of acarid hypopi occur on all species of Palearctic Bombus spp. Skou, Holm and Haas (1963) found 106 nymphs of Parasitus fucorum on a hibernating queen. In order to get an indication of where mites occur on Michigan Bombinae and how many mites occur in each area, counts of incidences of infestation were made from bees collected and recorded in 1963. An incidence is defined as the finding of one or more mites on a particular anatomical part.

The sample collected will not agree with the total number of bees with mites in the previous section due to the loss of some mites and lack of appropriate data for all specimens. This is due in part to a technique which did not work. Some of the bees caught in 1963 were stored in individual vials in the refrigerator and freezer after they had been examined alive through the glass wall of their closed containers. In some instances the mites moved off the bee. In other instances, the bee and mites decayed before all could be examined.

Incidences are recorded throughout the season from April through October and it is believed an adequate and representative sample was obtained.

The categories chosen, arbitrarily, are head, thorax, abdomen, wings and legs. These are further subdivided (table 8). Many instances such as intersegmental groove III of the thorax, propodeal spiracle, scutellum and propodeum are lumped together to give a workable basis for comparison of general areas of the bee. Living mites have been observed crawling on all external structures of bees in nests. The more common areas are illustrated in figures 35, 36 and 37. In some instances, mites remain alive after the bee has been killed and have been observed spreading to various parts of the bee and to the insect pin of pinned bees. An attempt was made to control this through use of potent killing jars. Mites found on the head, abdominal segment I and tibia III of the same bee appear as three separate incidences (table 8). All mites are lumped together in this study.

The most common site of mite infestation is the propodeum with 181 instances of infestation. Skou, Holm and Haas (1963) suggest that only after the propodeum and anterior portion of abdominal tergite I are occupied will hypopi be found on other parts of the body. The techniques used in this study are not adequate to test this statement. Since 56% of the incidences of infestation occur on this area of the bee, the hypothesis by Skou, Holm and Haas may be correct. However, bees which had numerous hypopi on the abdominal

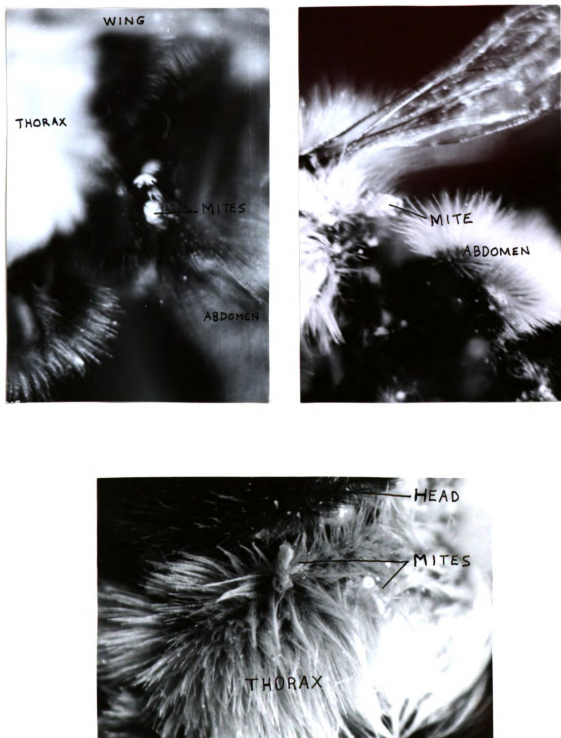


Figure 35. Position of mesostigmatid mites on Michigan Bombinae

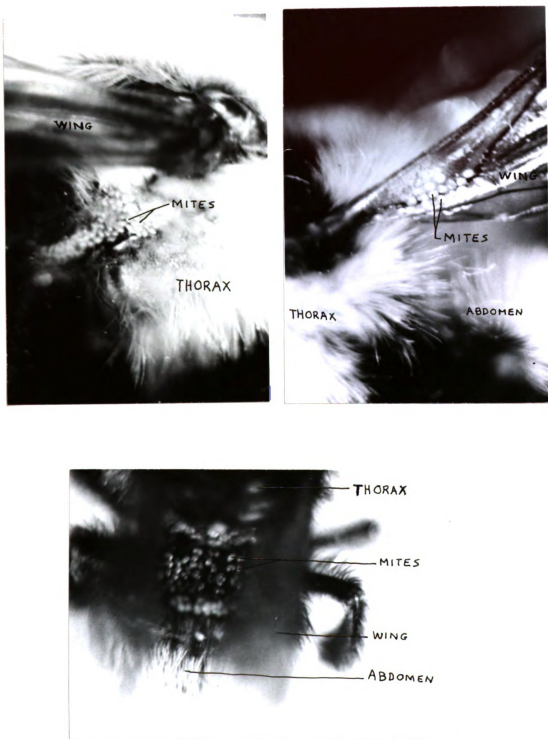


Figure 36. Acarid hypopi on thorax, wing and abdominal tergite I of Michigan Bombinae

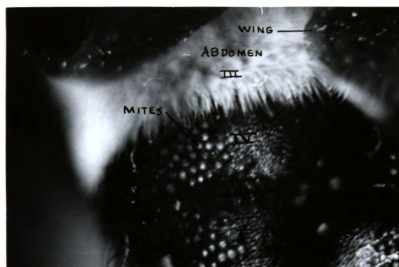
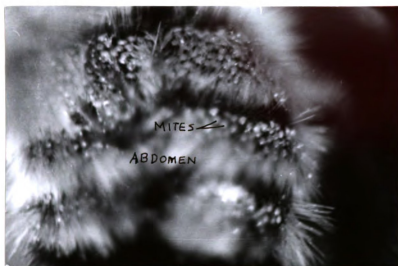


Figure 37. Acarid hypopi on abdominal tergites of Michigan Bombinae

Table 8. Position of mites on Michigan Bombinae collected
in 1963

	At Flower	In Nest	Total
Head	4	2	6
Thorax			250
Prothorax	1	7	
Propodeum	57	124	
Other (ventral, lateral, dorsal)	15	15	
Between thorax and abdomen	10	21	
Wings	8	45	53
Legs			56
Coxae	7	14	
Femur III	5	1	
Tibia	16	2	
Tarsus III	1	1	
Between legs and thorax	1	4	
Between legs and abdomen	1	3	
Abdomen			161
Segment I	19	69	
Segment II	17	3	
Segment III	14	3	
Segment IV	12	0	
Segment V	6	0	
Segment VI	4	0	
Segment VII	1	0	
Other (segment not recorded)	10	3	
Total	209	317	526

tergites and not on the propodeum or anterior aspect of the abdomen were not unusual.

Large numbers of mites have been found on Bombinae. One queen Bombus vagans collected in Kalamazoo County, Michigan on 27 April 1963 had 57 Scutacarus acarorum on the region of coxae II and III and 802 Kuzinia laevis hypopi on the thorax and abdomen. This is a partial count since two slides of scutacarids and two slides of K. laevis had been made from collections from the thorax and were not available at the time of this report. Of the 859 mites, 408 were removed from abdominal tergite II for counting while the remaining ones were counted in situ. This is difficult and the count is thought to be slightly lower than it would be if all mites were removed and counted. Although many hypopi are found on bees, this is one of the most heavily infested ones that was found.

To estimate how many mites may occur on various parts of male, female and worker bees, 170 Bombus pennsylvanicus from the nest previously discussed were examined for mites (tables 9, 10, 11, 12). When first examined, 57% of the bees had mites. Later, no mites could be found on four of these. The sample consists of 16 queens, 29 males and 48 workers. Fifteen mesostigmatid mites occurred on 14 bees. Both acarid hypopi and mesostigmatid mites occurred on the same bees. Approximately 2646 acarid hypopi were found on 207 anatomical parts of the 93 bees. The average number is approximately 28 mites per bee and 12.8 mites per anatomical part.

Table 9. Number of mites per body part for 29

male Bombus pennsylvanicus

Body Region	Hypopi	Hypopi Average	Mesostigmatid
Head	1(1)	1.0	0
Thorax			
Prothorax	6(3)	2.0	0
Propodeum	1062(29)	36.6	1(1)
Other (lateral)	39(1)	39.0	0
Between the thorax and abdomen	37(5)	7.4	2(2)
Wings	15(4)	3.8	
Legs			
Coxae	1(1)	1.0	1(1)
Between legs and thorax	3(1)	3.0	1(1)
Between legs and abdomen	0	0	1(1)
Abdomen			
Segment I	149(14)	10.6	0
Remaining segments	20(2)	10.0	0
Unknown (dropped from bee)	0	0	1(1)
Total	1323(61)	21.7	7(7)

Of the bees in this nest, the highest numbers of mites per bee part occurred in the males (table 9) followed by the workers (table 11) and queens (table 10) in that order. Why males carried more hypopi per anatomical part of the bee in this study is unknown. The activity patterns of the male in the nest vary from those of both workers and females but insufficient evidence exists to suggest this as a reason for

increased average numbers of mites.

The queens and males carried all but one of the fifteen mesostigmatid mites found. This pattern may be characteristic of the mites involved. Large numbers of Parasitus fucorum nymphs have been reported previously on a Bombus sp. queen (Skou, Holm and Haas 1963).

Table 10. Number of mites per body part for 17 queen

<u>Bombus pennsylvanicus</u>			
Body Region	Hypopi	Hypopi Average	Mesostigmatid
Head	0	0	0
Thorax			
Prothorax	0	0	0
Propodeum	50(7)	7.1	2(1)
Other (lateral)	1(1)	1.0	
Between thorax and abdomen	1(1)	1.0	2(2)
Wings	4(3)	1.3	0
Legs			
Tibia II	1(1)	1.0	0
Between legs and thorax	0	0	1(1)
Abdomen			
Segment I	12(2)	6.0	2(2)
Total	68(15)	4.5	7(6)

Table 11. Number of mites per body part of 48 worker

Bombus pennsylvanicus

Body Region	Hypopi	Hypopi Average	Mesostigmatid
Head	1(1)	1.0	0
Thorax			
Prothorax	2(2)	1.0	0
Propodeum	326(43)	7.6	1(1)
Other	3(3)	1.0	0
Between thorax			
and abdomen	24(4)	6.0	0
Wings	245(33)	7.4	0
Legs	1(1)	1.0	0
Abdomen			
Segment I	663(42)	15.8	0
Segment II	3(2)	1.5	0
Total	1267(131)	9.7	1(1)

The data for the bees in this nest suggest that not only are mites more likely to be found on the propodeum and abdominal segment I but that the largest numbers of mites will be found in this area (table 12). The order of magnitude from the highest to lowest numbers of mites per body part is propodeum, abdominal segment I, wings, thorax (other than propodeum), abdomen (other than segment I), legs and head. The 29 males carried half (1323) of the 2646 acarid hypopi counted on 93 Bombus americanorum males, queens and workers. The average numbers of hypopi per bee was (1) males, 21.7 (2) workers, 9.7 and (3) queens, 4.5.

Table 12. Summary of number of mites for 93

Bombus pennsylvanicus

Body Region	Hypopi	Hypopi Average	Mesostigmatid
Head	2(2)	1.0	0
Thorax			
Propodeum	1438(79)	18.2	4(3)
Other	113(20)	5.7	4(4)
Wings	264(40)	6.6	
Legs	3(3)	1.0	1(1)
Between legs and thorax	3(1)	3.0	2(2)
Between legs and abdomen	0	0	1(1)
Unknown	0	0	1(1)
Abdomen			
Segment I	824(58)	14.2	2(2)
Other	23(4)	5.8	0
Total	2646(207)	12.8	15(14)

CHECK LIST OF MITES ASSOCIATED WITH MICHIGAN BOMBINAE

Phylum Arthropoda

Subphylum Chelicerata

Class Arachnida

Subclass Acarina

Order Mesostigmata

Cohort Uropodina

Family Uropodidae

Genus Fuscuropoda sp.

Uropoda sp.

Family Urodinychidae

Genus Leiodinychus sp.

Cohort Gamasina

Family Parasitidae

Genus Parasitus sp.

Family Phytoseiidae

Genus Typhlodromus sp.

Family Blattisociidae

Genus Proctolaelaps sp.

Proctolaelaps longanalis

Proctolaelaps longisetosus

Proctolaelaps ornatus

Family Laelaptidae

Genus Pneumolaelaps sp.

Pneumolaelaps mistipilus Hunter 1966

Pneumolaelaps longipilus Hunter 1966

Pneumolaelaps longanalis new species

Family Laelaptidae (cont'd)

Genus Pneumolaelaps new species APneumolaelaps new species BPneumolaelaps new species CPneumolaelaps new species DCosmolaelaps sp.Androlaelaps sp.

Family Veigaiidae

Order Prostigmata

Family Podapolipodidae

Genus Locustacarus sp.Locustacarus (Bombacarus) buchneri

Family Pyemotidae

Family Scutacaridae

Genus Scutacarus sp.Scutacarus acarorum

Family Tarsonemidae

Family Tydeidae

Genus Tydeus sp.

Family Cunaxidae

Genus Cunaxa sp.

Family Stigmaeidae

Family Anystidae

Family Cheyletidae

Genus Cheyletus sp.

Family Smarididae

Family Trombidiidae

Genus Eutrombidium sp.

Order Astigmata

Family Acaridae

Genus Kuzinia sp.Kuzinia laevisTyrophagus sp.Tyrophagus putrescentiaeCaloglyphus sp.Rhizoglyphus sp.

Family Saproglyphidae

Genus Vidia sp.Calvolia sp.

Family Glyciphagidae

Genus Ctenoglyphus sp.Ctenoglyphus robustus

Family Anoetidae

Genus Histiostoma sp.

Family Epidermoptidae

Genus Dermatophagoides sp.

Order Cryptostigmata

Family Nothridae

Genus Nothrus sp.

Family Phthiracaridae

MITES ASSOCIATED WITH MICHIGAN BOMBINAE IN NESTS

Species of Bombinae	Acarina	County
<u>Bombus affinis</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo
	<u>Tyrophagus putrescentiae</u>	Kalamazoo
	Parasitidae	Kalamazoo
	Stigmaeidae	Kalamazoo
	<u>Scutacarus acarorum</u>	Kalamazoo
<u>Bombus bimaculatus</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Pneumolaelaps longanalis</u>	Kalamazoo
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo
	<u>Tyrophagus putrescentidae</u>	Kalamazoo
	<u>Ctenoglyphus robustus</u>	Kalamazoo
	Parasitidae	Kalamazoo
	Anystidae	Kalamazoo
	Smarididae	Kalamazoo
	<u>Cunaxa</u> sp.	Kalamazoo
<u>Bombus fervidus</u>	<u>Pneumolaelaps longipilus</u>	Kalamazoo
	<u>Pneumolaelaps longanalis</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo,
		Allegan
	<u>Tyrophagus putrescentiae</u>	Kalamazoo
	<u>Ctenoglyphus</u> sp.	Kalamazoo
	<u>Scutacarus acarorum</u>	Allegan
	<u>Tydeus</u> sp.	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE IN NESTS (cont'd)

Species of Bombinae	Acarina	County
<u>B. fervidus</u> (cont'd)	<u>Leiodynchus</u> sp.	Kalamazoo
	Parasitidae	Kalamazoo
	Uropodidae	Kalamazoo
	Pthiracaridae	Kalamazoo
<u>Bombus</u> <u>griseocollis</u>	<u>Kuzinia</u> <u>laevis</u>	Kalamazoo
	<u>Cheyletus</u> sp.	Kalamazoo
	Parasitidae	Kalamazoo
	Phytoseidae	Kalamazoo
<u>Bombus</u> <u>pennsylvanicus</u>	<u>Pneumolaelaps</u> sp.	Kalamazoo
	<u>Pneumolaelaps</u> <u>mistipilus</u>	Kalamazoo
	<u>Pneumolaelaps</u> <u>longipilus</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo,
		Allegan
	<u>Proctolaelaps</u> <u>longisetosus</u>	Kalamazoo
	<u>Cosmolaelaps</u> sp.	Kalamazoo
	<u>Androlaelaps</u> <u>glasgowi</u> (?)	Kalamazoo
	<u>Parasitus</u> sp.	Allegan,
		Kalamazoo
	<u>Uropoda</u> sp.	Kalamazoo
	<u>Fuscuropoda</u> sp.	Kalamazoo
	<u>Leiodynchus</u> sp.	Kalamazoo
	Cheyletidae	Kalamazoo
	Stigmaeidae	Kalamazoo
	<u>Kuzinia</u> <u>laevis</u>	Kalamazoo
	<u>Ctenoglyphus</u> sp.	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE IN NESTS (cont'd)

Species of Bombinae	Acarina	County
<u>B. pennsylvanicus</u> (cont'd)	<u>Histiostoma</u> sp.	Kalamazoo
	Tarsonemidae	Kalamazoo
	<u>Nothrus</u> sp.	Kalamazoo
	<u>Scutacarus acarorum</u>	Kalamazoo
<u>Bombus vagans</u>	<u>Pneumolaelaps</u> sp.	Kalamazoo
	Parasitidae	Barry
	<u>Ctenoglyphus</u> sp.	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER

Species of Bombinae	Acarina	County
<u>Bombus affinis</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Androlaelaps casalis</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Proctolaelaps longanalis</u>	Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo, Alpena, Genesee
	<u>Ctenoglyphus</u> sp.	Kalamazoo
	<u>Vidia</u> sp.	Kalamazoo
	Parasitidae	Kalamazoo
	<u>Scutacarus acarorum</u>	Kalamazoo, Ingham, Lenawee
<u>Bombus bimaculatus</u>	<u>Kuzinia laevis</u>	Allegan, Ingham, Kalamazoo, Oceana
	<u>Scutacarus acarorum</u>	Kalamazoo
	Parasitidae	Kalamazoo, Oceana
	<u>Locustacarus buchneri</u>	Allegan, Kalamazoo
	<u>Proctolaelaps longanalis</u>	Kalamazoo
	<u>Pneumolaelaps longanalis</u>	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>Bombus borealis</u>	<u>Kuzinia laevis</u>	Delta
<u>Bombus fervidus</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Pneumolaelaps longipilus</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Proctolaelaps ornatus</u>	Kalamazoo
	Parasitidae	Luce, Kalamazoo
	<u>Dermatophagoides</u> sp.	Luce
	<u>Kuzinia laevis</u>	Delta, Ingham, Kalamazoo, Luce
	<u>Calvolia</u> sp.	Allegan
	<u>Scutacarus acarorum</u>	Kalamazoo, Allegan, Alger
	<u>Rhizoglyphus</u> sp.	Luce
	Oribatei	Allegan, Kalamazoo
<u>Bombus griseocollis</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo Huron
	<u>Pneumolaelaps longanalis</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>B. griseocollis</u> (cont'd)	<u>Caloglyphus</u> sp.	Cheboygan
	<u>Scutacarus acarorum</u>	Branch, Huron, Kalamazoo
	Parasitidae	Kalamazoo
<u>Bombus impatiens</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo, Ingham
	Parasitidae	Kalamazoo
	<u>Scutacarus acarorum</u>	Lenawee, Barry
<u>Bombus nevadensis</u>	<u>Pneumolaelaps mistipilus</u>	Kalamazoo
	<u>Pneumolaelaps</u> sp.	Allegan
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Scutacarus acarorum</u>	Kalamazoo, Missaukee
	<u>Kuzinia laevis</u>	Kalamazoo
	Parasitidae	Kalamazoo
<u>Bombus pennsylvanicus</u>	<u>Pneumolaelaps longipilus</u>	Berrien, Clinton, Lapeer, Oceana
	<u>Pneumolaelaps longanalis</u>	St. Joseph
	<u>Proctolaelaps longanalis</u>	Kalamazoo

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>B. pennsylvanicus</u> (cont'd)	<u>Proctolaelaps</u> sp.	St. Joseph
	<u>Proctolaelaps longisetosus</u>	Kalamazoo
	<u>Proctolaelaps ornatus</u>	Kalamazoo
	<u>Kuzinia laevis</u>	Genesee, Kalamazoo, Kent
	<u>Scutacarus acarorum</u>	Bay, Kalamazoo, Ingham, Oceana
	Parasitidae	Barry, Kalamazoo, Kent
<u>Bombus rufocinctus</u>	<u>Kuzinia laevis</u>	Alger
<u>Bombus ternarius</u>	<u>Kuzinia laevis</u>	Alger, Alpena, Delta, Houghton, Marquette, Schoolcraft
	<u>Scutacarus acarorum</u>	Houghton, Alger, Delta, Schoolcraft
(in killing jar)	<u>Eutrombidium</u> sp.	Delta

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>B. ternarius</u> (cont'd)	<u>Pneumolaelaps</u> sp.	Delta
<u>Bombus terricola</u>	<u>Kuzinia laevis</u>	Alger, Alpena, Baraga, Delta, Houghton, Ingham, Macinac, Marquette, Missaukee, Ontonagon, Schoolcraft
	<u>Scutacarus acarorum</u>	Delta, Baraga, Houghton, Ontonagon, Schoolcraft
	<u>Pneumolaelaps</u> sp.	Alpena, Baraga
	<u>Caloglyphus</u> sp.	Ontonagon
	Parasitidae	Alpena
(In killing jar)	<u>Eutrombidium</u> sp.	Delta
	<u>Typhlodromus</u> sp.	Luce

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>Bombus vagans</u>	<u>Kuzinia laevis</u>	Alger, Allegan, Barry, Delta, Lenawee, Marquette, Ontonagon, Kalamazoo, Oceana, Keweenaw
	<u>Scutacarus acarorum</u>	Lenawee, Kalamazoo, Alpena, Alger
	Parasitidae	Lenawee
	<u>Caloglyphus</u> sp.	Alger
	<u>Vidia</u> sp.	Kalamazoo
	<u>Pneumolaelaps longanalis</u>	Kalamazoo
	<u>Locustacarus buchneri</u>	Kalamazoo
	Pyemotidae	Kalamazoo
<u>Psithyrus ashtoni</u>	<u>Kuzinia laevis</u>	Ontonagon, Alger, Keweenaw
	Scutacaridae	Alger
	<u>Pneumolaelaps longanalis</u>	Ontonagon
	<u>Rhizoglyphus</u> sp.	Alpena

MITES ASSOCIATED WITH MICHIGAN BOMBINAE AT FLOWER (cont'd)

Species of Bombinae	Acarina	County
<u>Psithyrus laboriosus</u>	<u>Locustacarus buchneri</u>	Kalamazoo
	<u>Scutacarus acarorum</u>	Barry, Kalamazoo
	<u>Kuzinia laevis</u>	Kalamazoo
<u>Psithyrus fernaldae</u>	<u>Kuzinia laevis</u>	Keweenaw

THE DISTRIBUTION OF PNEUMOLAE LAP S spp. IN NORTH AMERICA
WITH DESCRIPTIONS OF A NEW SPECIES (ACARINA: LAELAPTIDAE)

Both Hunter (1966) and Evans and Till (1966) recently reviewed the status of Pneumolaelaps spp. Hunter published a complete list of synonymy. In this present report, new host and distribution records of the three North American species described by Hunter are given. A new species of Pneumolaelaps is described and illustrated.

Pneumolaelaps mistipilus Hunter 1966 has been reported from Georgia and from Kalamazoo County, Michigan. Collections were made from the following Bombinae: B. bimaculatus, B. fervidus, B. griseocollis and B. nevadensis. Distribution records are given in table 13.

Pneumolaelaps aequalipilus Hunter 1966 has been reported from Georgia. Collections were made from Bombus impatiens and B. pennsylvanicus. Distribution records are listed in table 14.

Pneumolaelaps longipilus Hunter 1966 has been reported from Bombus pennsylvanicus in Georgia. Distribution records are listed in table 15.

Of the three species known from North America, Pneumolaelaps aequalipilus appears to be southern in distribution while both P. longipilus and P. mistipilus appear to be more cosmopolitan in distribution throughout the eastern United States. The latter two species have longer body setae than P. aequalipilus. It might be hypothesized that the shorter body setae may have some connection with the northern limits

Table 13. Distribution of Pneumolaelaps mistipilus Hunter
1966

Species of Bombinae	State	Month Collected
<u>B. affinis</u>	Michigan (Kalamazoo Co.)	Apr., July, Aug.
<u>B. bimaculatus</u>	Michigan (Kalamazoo Co.)	Apr., May
	Missouri	April
<u>B. fervidus</u>	Michigan (Kalamazoo Co.)	May
<u>B. griseocollis</u>	Michigan (Kalamazoo Co.)	May, Aug.
	Michigan (Huron Co.)	May
<u>B. impatiens</u>	Michigan (Kalamazoo Co.)	August
	Illinois	April
	Kansas	unknown
	Louisiana	March
	Georgia	Aug., Oct.
<u>B. nevadensis</u>	Michigan (Kalamazoo Co.)	May, July, Aug.
	Illinois	April
	Missouri	Apr., Aug., Sept.
<u>B. pennsylvanicus</u>	Michigan (Kalamazoo Co.)	May, Aug.
	Arkansas	Sept.
	Kansas	July, Sept.
	Georgia	Apr., June

Table 14. Distribution of Pneumolaelaps aequalipilus

Species of Bombinae	State	Month Collected
<u>Bombus impatiens</u>	Georgia	April
<u>B. pennsylvanicus</u>	Alabama	April
	Florida	no date
	Georgia	May, June
	Illinois	May
	Kansas	June, Aug.
	Louisiana	Mar., Sept., Oct.
	Missouri	June
	South Carolina	May
	Texas	July

Table 15. Distribution of Pneumolaelaps longipilus

Species of Bombinae	State	Month Collected
<u>Bombus fervidus</u>	Michigan (Kalamazoo Co.)	Aug., Sept.
<u>B. nevadensis</u>	Indiana	Sept.
<u>B. pennsylvanicus</u>	Georgia	Apr., May, July Aug., Oct.
	Iowa	unknown
	Kansas	May
	Minnesota	April
	Michigan	May, June, July

of this species. However, the new species which is described in this report has short body setae and is northern in distribution.

Pneumolaelaps longanalis new species

This species may be separated from all known species by the following combination of characters. Dorsal plate completely covers the dorsum. Dorsal setae short, not extending beyond the base of the next posterior row of setae. First pair of sternal setae do not reach the bases of the third pair. Anal plate longer than wide. Distinct striations on the presternal, sternal and genitoventral plates.

Female: Body oval; 572 μ long, 372 μ wide. Dorsum: Dorsal plate covering all of dorsum (figure 38); no integument laterad of plate. Setae short, up to 32 μ long, except for il (setal notations following Costa 1961), not overlapping the base of the next posterior row, a row of heavier setae along margin of body; setae il thickest. Entire surface of dorsal plate marked by scale like striations. Ventrums: Presternal plate with several striations (figure 39). Sternal plate 80 μ long on midline, 140 μ at narrowest width between coxae II; anterolateral corner extends in a T-shape between and laterad of coxae I and II, striations of plate extend to third pair of sternal setae but are less obvious along the posterior border and postero-mesal portions of the sternal plate. Sternal setae heavy, thick at base, first pair not reaching the base of the third pair, relative lengths as shown in figure 39. Metasternal plates weakly sclerotized mesially, metasternal setae about the same size as the sternal setae. Genito-ventral plate slightly overlapping sternal, 311 μ long on midline, 161 μ at greatest width, rounded

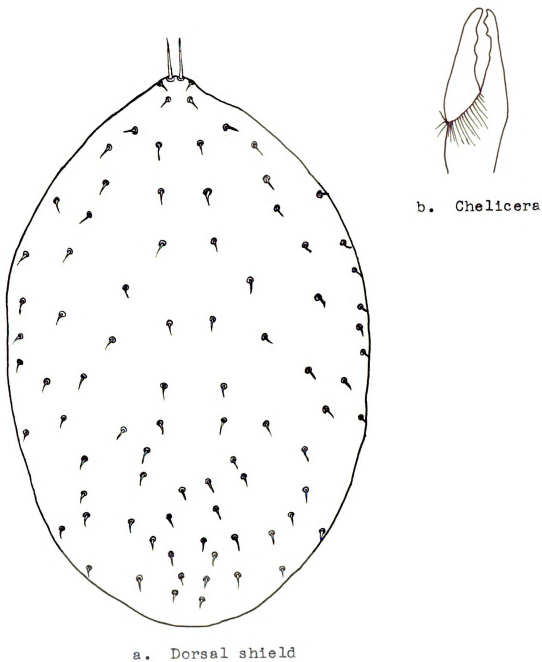


Figure 38. *Pneumolaelaps longanalis* n. sp.,
dorsal aspect, female

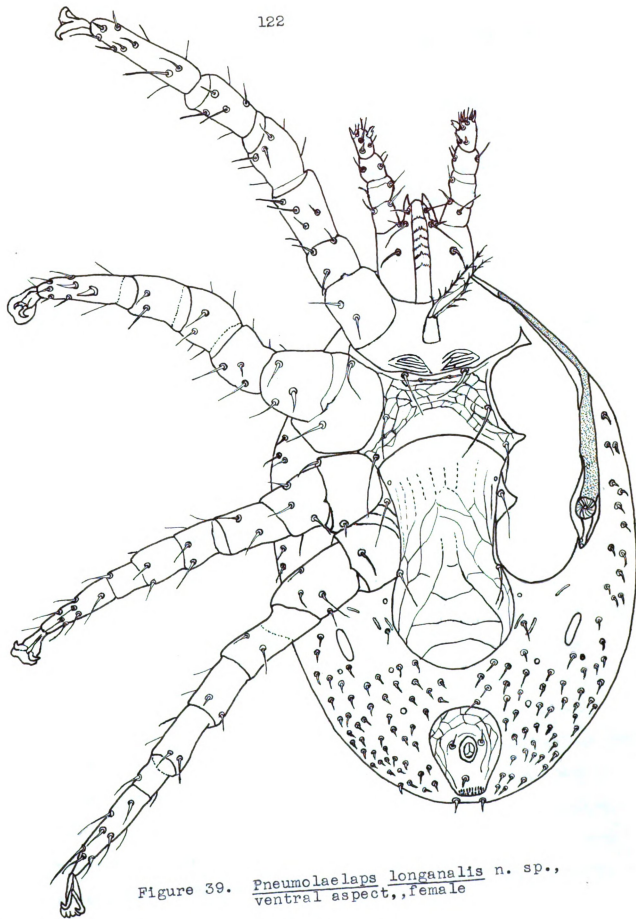


Figure 39. *Pneumolaelaps longanalis* n. sp.,
ventral aspect,,female

posteriorly, slightly expanded beyond genital setae; genital setae shorter than metasternal setae, extending approximately one half the distances from their bases to the posterior margin of plate. Striations are pronounced and form a vase-like pattern mesially. Anal plate pear-shaped, 103μ long, 96μ wide, tapering to 22μ at the posterior border; narrowed and bluntly rounded posteriorly with striations on the posterior border; striations diminishing posteriorly (figure 39). One large metapodal plate, with a smaller plate anterior to it and two rod like plates at base of first ventral plate setae. Peritremal plate large extending to dorsal plate in area of setae rl; extending posterior of stigmata, two small pores in posterior tip of plate; peritreme wide, extending to area of coxa I but not to dorsal surface; stigmatal opening large. Ventral body setae short, most about as long as distance between setal rows; two pairs between genito-ventral and anal plates; on lateral margins setae extend anterior to stigmatal opening; pores in integument as shown. Legs: Legs II heaviest; relative length and thickness of setae as indicated. Dorsal leg setae short. All tarsi with claws and caruncle. Chaetotaxy (following Evans 1963) given in Table 13.

Gnathosoma: Deuterostomal groove with six rows of teeth, first three anterior rows each with 1-2 large and 3-4 smaller teeth, three posterior rows with one large and 2-3 smaller teeth. Internal posterior rostral setae distinctly longer than other setae on the gnathosoma. Corniculi short, well sclerotized. Palps moderately heavy. Chelicerae chelate,

both fixed and movable digits with two teeth (figure 38).

Table 16. Pneumolaelaps longanalis, female, leg chaetotaxy

Leg	Trochanter	Femur	Genu	Tibia
I	1 $\frac{2}{3}$ 0	2 $\frac{5}{4}$ 2	2 $\frac{33}{21}$ 2	2 $\frac{33}{21}$ 2
II	1 $\frac{0}{3}$ 1	2 $\frac{5}{3}$ 1	2 $\frac{32}{11}$ 2	2 $\frac{22}{11}$ 2
III	1 $\frac{0}{3}$ 1	1 $\frac{3}{1}$ 1	2 $\frac{22}{11}$ 1	2 $\frac{12}{11}$ 1
IV	1 $\frac{0}{3}$ 1	1 $\frac{3}{1}$ 1	2 $\frac{23}{11}$ 2	2 $\frac{23}{11}$ 1

Male: Body oval; 612 μ long, 380 μ wide. Dorsum: Dorsal plate covering all of dorsum (figure 40); no integument visible laterad of plate. Setae short, up to 26 μ long except for sl (setal notations following Costa 1961), not overlapping the base of the next row; setae il thickest. Entire surface of dorsal plate marked by scale like striations. Ventrum: No presternal plate (figure 41). Ventral plates coalesced to form holovenral plate; expanded posterior to coxae IV; 472 μ long, 110 μ wide between coxae II, 76 μ wide between coxae IV, plate widest behind coxae IV - 260 μ ; anterolateral corner extends between coxae I and II, striations on entire holovenral plate; striations more prominent along the margins of plate. Sternal setae heavy, thick at base, not extending to anal setae, behind the genital setae as indicated (figure 40). Peritremal plate large extending to dorsal surface in area of setae rl; extending posterior of stigmata, two small pores in posterior tip of plate; peritreme wide, extending to area of coxa I but not to dorsal

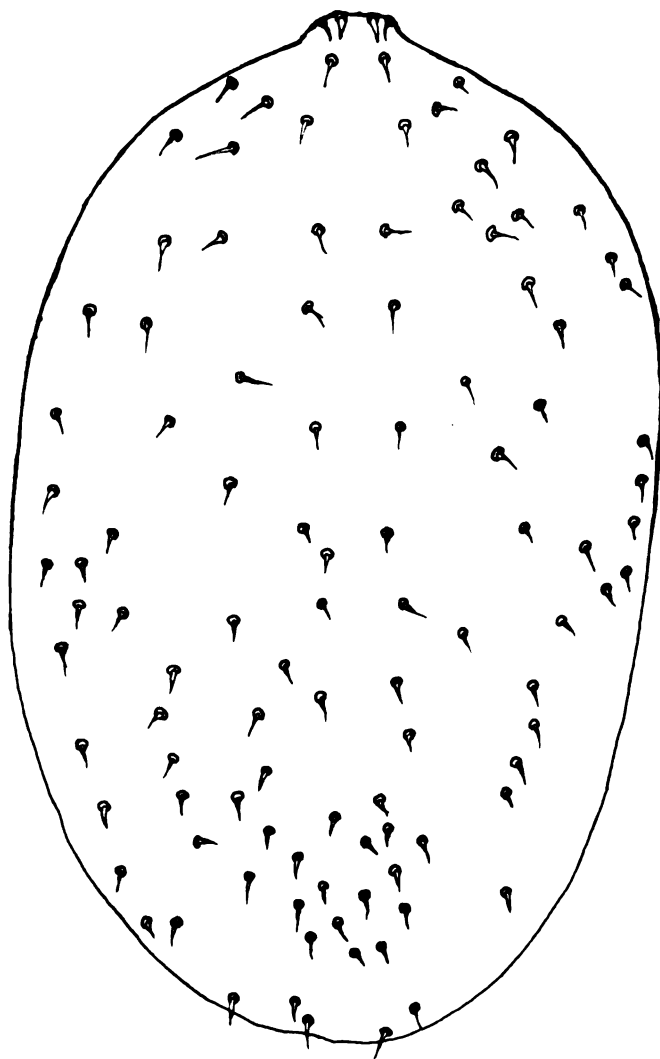


Figure 40. Pneumolaelaps longanalis n. sp.,
dorsal aspect, male

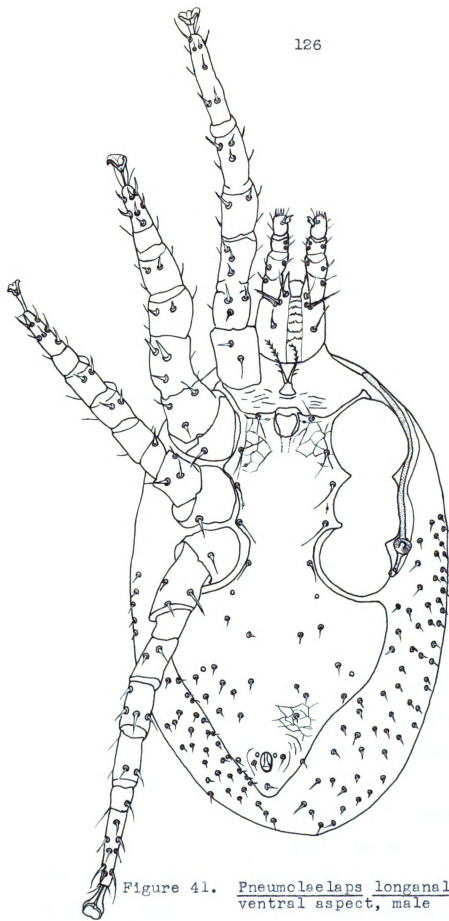


Figure 41. *Pneumolaelaps longanalis* n. sp.,
ventral aspect, male

surface; stigmal opening large. Ventral body setae short, most shorter than distance between setal rows; on lateral margins setae extend anterior to stigmal opening; pores in integument as shown.

Legs: Legs II heaviest; relative length and thickness of setae as indicated. Dorsal leg setae short. All tarsi with claws and caruncle. Femur II with a thick ventral seta. All legs with ventral setae thicker than in female. Deutero-stomal groove with six rows of teeth, first three anterior rows with eight teeth, three posterior rows with 3-6 teeth. Internal rostral setae distinctly longer than the other setae on the gnathosoma. Corniculi short well sclerotized. Palps moderately heavy. Chelicerae chelate.

Holotype (female): Gull Lake Biological Station, Kalamazoo County, Michigan, 10 August 1964-4; collector R. W. Husband; from petiole region of Bombus griseocollis (DeGeer) female.

Allotype (male): Farm meadow, Macdonald College, Province of Quebec, Canada, 13 August 1965; collector G. Jamieson; from nest of Bombus sp.

Paratypes: All were collected in Kalamazoo County, Michigan by R. W. Husband unless otherwise noted. Four miles west of Kalamazoo, 11 August 1963-2, on Bombus griseocollis female: 1 female. Four miles west of Kalamazoo, 3 August 1963-5, on Bombus griseocollis female: 1 female. Five miles west of Kalamazoo, 11 September 1963-3, from petiole region of Bombus vagans male: 1 female. West side Kalamazoo,

26 July 1963-7, from Bombus bimaculatus: 1 female. Gull Lake Biological Station, 12 August 1965, from nest of Bombus bimaculatus: 1 female. Gull Lake Biological Station, 5 August 1965-2, from Bombus bimaculatus female in nest: 1 female. Four miles west of Kalamazoo, 7 August 1963, on Bombus griseocollis female: 1 female. Gull Lake Biological Station, 5 August 1965, from nest of Bombus bimaculatus: 1 female, 2 nymphs. Gull Lake Biological Station, 11 August 1965, from nest of Bombus bimaculatus: 6 females. Gull Lake Biological Station, 13 August 1965, from nest of Bombus bimaculatus: 2 females, 1 nymph. Northwest Kalamazoo, 4 September 1963, from nest of Bombus fervidus: 2 females. Nottawa, St. Joseph County, 31 August 1933, collector C. Sabrosky, from Bombus pennsylvanicus: 1 female. Creve Coeur Lake, St. Louis County, Missouri, 2 September 1956, collector E. P. Meiners, from Bombus pennsylvanicus: 1 female. Logan, Utah, 27 June 1956, collectors G. E. Bohart, A. Locker, E. Cross, from nest of Bombus morrisoni: 1 female. T42N, R21W, S19, Delta County, Michigan, 28 August 1965, collector T. W. Porter, from sealed collecting vial with Bombus ternarius and Bombus terricola: 3 females. T51N, R42W, S14, Ontonagon County, Michigan, 28 August 1965, collector T. W. Porter in a sealed collecting vial with Bombus terricola, B. vagans and Psithyrus ashtoni: 1 female. Farm meadow, Macdonald College, Province of Quebec, Canada, 13 August 1965, collector G. Jamieson; from nest of Bombus sp.: 2 females (2 slides).

The holotype and four paratypes will be deposited with the U. S. National Museum, Washington D. C. Paratypes will be deposited with the Institute of Acarology, Wooster, Ohio; Bishop Museum, Honolulu; British Museum (Natural History); and the Entomology Museum, Michigan State University, East Lansing, Michigan. The distribution is northern United States and Southern Canada (table 17).

Table 17. Distribution of Pneumolaelaps longanalis n.sp.

Species of Bombinae	State	Month Collected
<u>Bombus bimaculatus</u>	Michigan (Kalamazoo Co.)	July, August
<u>B. fervidus</u>	Michigan (Kalamazoo Co.)	September
<u>B. griseocollis</u>	Michigan (Kalamazoo Co.)	August
<u>B. morrisoni</u>	Utah, Logan	June
<u>B. pennsylvanicus</u>	Michigan (St. Joseph Co.)	August
<u>B. ternarius</u> and		
<u>B. terricola</u>	Michigan (Delta Co.)	August
<u>B. terricola</u> ,		
<u>B. vagans</u> and		
<u>Psithyrus ashtoni</u>	Michigan (Ontonagon Co.)	August
<u>Bombus vagans</u>	Michigan (Kalamazoo Co.)	September
<u>Bombus</u> sp.	Quebec, Canada	August
<u>B. pennsylvanicus</u>	Missouri (St. Louis Co.)	September

RELATIONSHIPS BETWEEN ACARINA AND BOMBINAE

This section is concerned with distribution, nest colonization and food habits of Michigan Acarina found in or on Michigan Bombinae or in their nests.

The literature on distribution and food habits of various genera and species of mites, although incomplete, is very extensive. In this study, the works of Baker and Wharton (1952), Zakhvatkin (1941) and Hughes (1961) are the main sources of information on world wide distribution and food habits for various genera and species. The latter two references are mainly concerned with mites of stored products.

DISTRIBUTION OF MICHIGAN ACARINA ASSOCIATED WITH BOMBINAE

A majority of the investigations were conducted in Kalamazoo County. Large numbers of Bombinae from this county have yielded 11 families of mites in addition to 12 families which were listed by Homann (1935) from hives of Apis mellifica in Germany. On the basis of incomplete information for many genera and species, distribution patterns for mites are difficult to discern. Four common species are illustrated in figures 42 and 43.

Kuzinia laevis has been collected throughout the state from Isle Royale to the southern counties (figure 42). It has been collected from 15 species of Bombinae in Michigan. Additional K. laevis have been obtained from Wisconsin, Minnesota and Illinois Bombinae. Thorp (personal communication 1963) found K. laevis on California Bombinae.

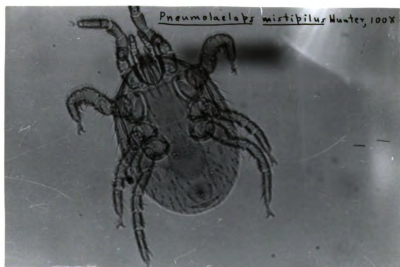
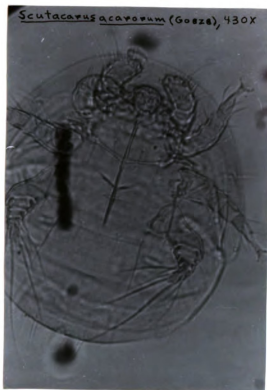


Figure 42. Scutacarus acarorum (Goeze),
Kuzinia laevis (Dujardin)
 and Pneumolaelaps mistipilus Hunter

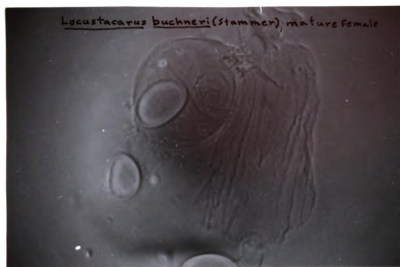


Figure 43. Locustacarus buchneri (Stammer)

Zakhvatkin (1941) states that K. laevis is found as far north as Greenland and may be found wherever Bombinae are found. The species is found throughout Europe and northern Asia. The southern limits have not been established.

Scutacarus acarorum was found in seventeen counties throughout the state on twelve species of Bombinae at flower and on Bombus affinis, B. fervidus and B. pennsylvanicus in nests (figure 42). Bees in an underground B. affinis nest were particularly heavily infested. This species has been taken from Bombinae collected in Georgia, Illinois, Kansas, Missouri, New York and Tennessee. S. acarorum is associated with Bombinae in Europe. Cross (personal communication 1966) recently saw a specimen of S. acarorum collected in Mongolia.

The genus Pneumolaelaps has a wide distribution pattern in Michigan and Eastern United States. Present records indicate that P. aequalipilus is found in the southeastern United States and that P. longipilus and P. mistipilus are found throughout the eastern United States. Thus far, the genus has been found in three upper peninsula counties as well as several counties in lower Michigan. The nests of all seven species of bees for which nests were collected contained Bombus sp. bearing Pneumolaelaps sp. Four additional species of Bombinae caught at flower also carried Pneumolaelaps spp. (figure 42).

Both nymph and adult male and female Parasitidae were found in nests of six species of Bombinae from Allegan,

Barry and Kalamazoo Counties. Only nymphs were taken from nine species of Bombinae in seven counties from Luce County in the upper peninsula to Kalamazoo and Lenawee Counties in the south. Parasitus fucorum was reported by Banks (1919) from Bombus sp. in northern Canada. Frison (1926) found Parasitus sp. in Illinois. Plath (1934) found Parasitus fucorum in the eastern United States. Thorp (personal communication 1963) found Parasitidae on California Bombinae. Parasitidae associated with Bombinae have been reported by several authorities in Europe (Vitzthum 1943, Skou, Holm and Haas 1963).

Proctolaelaps spp. were found on six species of Bombinae in Kalamazoo and St. Joseph counties. Lindquist (personal communication 1966) reports Proctolaelaps bombophilus from North American Bombinae. Proctolaelaps longisetosus was found in the nests of two species of Bombus spp. Proctolaelaps sp. may eventually be found throughout the state but are less common on bees than Pneumolaelaps sp. and Parasitidae.

Locustacarus buchneri was collected in three Bombinae in Allegan, Kalamazoo and Lenawee counties (figure 43). Sinha (personal communication 1966) found Locustacarus sp. in Bombus terricola in Canada. This species may be found throughout the state. On the basis of present data, this seems to be the only mite which is relatively host specific. Only one male Psithyrus laboriosus and one male Bombus vagans have been found to bear this mite. These species of Bombinae

occasionally are found in Bombus bimaculatus nests.

Records of mites found on Psithyrus sp. tend to follow the pattern of mites found on Bombus sp. with the exception that none of the predaceous mesostigmatids have been collected from them.

No distribution or association patterns are evident for the remaining species of mites. More data are needed for these species.

NEST COLONIZATION BY ACARINA

Norberg (1936) and Woodruffe (1953) have studied mites and insects in bird nests and have several explanations for the ways by which arthropods could colonize bird nests. With some modification the same possibilities for colonization of Bombinae nests by Acarina exist. A discussion of these possibilities will be presented later in this report.

Bombinae nests are usually constructed in the nests of rodents and would be expected to have at least some of the fauna characteristically associated with the previous occupants. Sixteen of the families of Acarina found by Drummond (1957) in rodent nests have also been found on Michigan Bombinae or in their nests. Eleven genera are common to both. Problems in identification of larval and nymph stages and in getting species opinions have prevented the making of many species comparisons. Haemolaelaps glasgowi which is so common in nests and on rodents throughout the United States was found in a Bombinae nest. The specimen is in poor condition and was identified by Lindquist as "Androlaelaps (Haemolaelaps)

near glasgowi". Some of the parasitic insects such as Siphonaptera have been found in nests of Bombinae and rodents. Many of the predaceous and detritus feeding mites are common to both Bombinae and rodent nests. Few species of host specific vertebrate parasites are found in Bombinae nests.

Mites could enter nests by (1) transportation on nest material at the time the vertebrate constructed the nest (2) transportation on the vertebrate animal (usually rodent) (d) transportation on the species of Bombinae queens, males or workers indigenous to the nest (4) transportation on invading Psithyrus sp. queens and other Bombus spp. (5) transportation on Lepidoptera, Diptera, Coleoptera, Hymenoptera or other arthropods such as isopods, spiders, millipedes and centipedes which invade the nest (7) transportation on Mollusca, Annelida or other invertebrates (8) transportation on other acarina (Scutacaridae on Parasitidae) and (9) deliberate entrance.

Norberg (1936) studied experimentally the means by which arthropods enter bird nests and concluded that some arthropods search for nests actively but no mites were observed to do this. The colonization of the nest by mites can be adequately explained by transportation upon nest material, upon the vertebrate which constructed the nest, upon Bombinae and a host of invertebrate invaders of the nest.

FOOD HABITS OF MICHIGAN ACARINA ASSOCIATED WITH BOMBINAE

A number of acarologists have discussed various types of associations between insects and mites (Vitzthum 1941, Trägårdh 1943, Evans, Sheals and Macfarlane 1961). The four major categories usually suggested are (1) commensal (2) phoretic (3) predaceous and (4) parasitic. A fifth category, no close relationship, could be utilized for such mites as the Phthiracaridae which is reported to feed upon decaying leaves and wood. The categories used by Drummond (1957) for mites found in mouse nests is a simplified form of the categories above. He utilized the categories (1) predaceous (2) parasitic and (3) miscellaneous. The miscellaneous category included such feeding habits as phytophagous, saprophagous, fungivorous, coprophagous and other non-predaceous and non-parasitic feeding habits. Drummond's system is the one that will be utilized in this report.

Evans, Sheals and Macfarlane (1961) indicate the food habits of some mites vary depending upon the availability of food. The use of such categories as predaceous and phytophagous cannot be interpreted in an exclusive sense as some mites may be predaceous at one time and phytophagous at another. The feeding habits in this report are the primary feeding habits of the mites when abundant food is available.

FOOD HABITS OF ACARINA ASSOCIATED WITH MICHIGAN BOMBINAE

Acarina Parasitic-Predaceous-Miscellaneous

Mesostigmata

Uropodidae

Uropoda sp. X

Fuscuropoda sp. X

Urodinychidae

Leiodinychus sp. X

Parasitidae

Parasitus sp. X

Phytoseiidae

Typhlodromus sp. X

Blattisociidae

Proctolaelaps sp. X

Laelaptidae

Pneumolaelaps sp. X

Cosmolaelaps sp. X

Androlaelaps sp. X X

Prostigmata

Podapolipodidae

Locustacarus sp. X

Pyemotidae X

Scutacaridae

Scutacarus sp. X

Tarsonemidae X

Tydeidae X

Cunaxidae X

Prostigmata (cont'd)

Parasitic-Predaceous-Miscellaneous

Stigmaeidae	X
Anystidae	X
Cheyletidae	X
Smarididae	X
Trombididae	X

Astigmata

Acaridae

<u>Kuzinia</u> sp.	X
<u>Tyrophagus</u> sp.	X
<u>Caloglyphus</u> sp.	X
<u>Rhizoglyphus</u> sp.	X

Saproglyphidae

<u>Vida</u> sp.	X
<u>Calvolia</u> sp.	X

Glyciphagidae

<u>Ctenoglyphus</u> sp.	X
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Anoetidae

<u>Histiostoma</u> sp.	X
------------------------	---

Epidermoptidae

<u>Dermatophagoides</u> sp.	X
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Cryptostigmata

Nothridae	X
Phthiracaridae	X

Some biological relationships have been discussed in considering Locustacarus buchneri and the relative abundance of Kuzinia laevis on Bombus spp. The feeding habits of Kuzinia laevis are not definitely known but may be mycetophagous. No success was experienced in attempts to rear this species. The hypopi (deutonymphs) are phoretic and have non-functional mouth parts. Although the hypopi do not feed upon the bees, when present in sufficient numbers, they may cause the queen to abandon nest construction and cease foraging in a similar pattern to what occurs with high infestations of Parasitus sp. nymphs (Skou, Holm and Haas 1963). In moderate numbers, Kuzinia laevis probably has a commensal relationship to Bombinae and a few other bees (Xylocopa and Osmia) and may not be harmful.

A mesostigmatid mite, possibly Pneumolaelaps longanalis, entered the abdominal airsac of a female Bombus bimaculatus that was being inspected for internal mites. The mite appeared to insert chelicerae into the ventral abdominal sinus through the wall of the airsac. Fluid could be observed to course into the relatively transparent mite. The mite became swollen after nine minutes of intermittent feeding. In the following seven minutes it crawled in and out of the air sac, under the intestine and was noted to rub its hind legs together. It was transferred to a cotton stoppered vial and was subsequently lost when the vial was knocked to the floor.

There is very little direct evidence for parasitism of Bombinae by mesostigmatid mites. If the feeding habits described above are an indication of the feeding habits of some mites on Bombinae, feeding probably takes place in the nest when the bee is less active and feeding is rapid and intermittent. Feeding may be limited to immature bees.

Many of the mesostigmatid mites are predaceous on other insects in the nest. Others have a wide range of feeding habits. Androlaelaps (Haemolaelaps) casalis, found in rodent nests and in a kill jar with Michigan Bombus affinis, is not parasitic but may feed on blood exuding from abrasions, eggs of other mites, farinaceous materials or may be predaceous depending upon the availability of food.

Female Locustacarus buchneri were observed with chelicerae inserted into abdominal air sacs. A few mature females have been put on slides with a piece of the air sac to which they are attached. The males were not observed feeding.

Some Scutacaridae and Pyemotidae are insect parasites but no direct evidence of feeding activity was noted in this study. Two instances of pseudoparasitism of Scutacarus acarorum were noted. One was on Pneumolaelaps sp. and the other upon a veigaliid mesostigmatid.

In summary, many of the mite families, genera and species appear to occur throughout the state of Michigan in a non-obligatory relationship to Bombinae. Relationships vary from the nearly host specific parasitic Locustacarus buchneri found in Bombus bimaculatus to the cosmopolitan, phoretic hypopi of Kuzinia laevis found on nearly every species of Michigan Bombinae throughout the state. The closeness and nature of the relationships of many species of mites has not yet been determined.

SUMMARY

Locality data for more than 15,000 Michigan Bombinae was used in determining the distribution of the sub-family Bombinae in Michigan. The systematics of Michigan Bombinae were reviewed and keys to species were presented. Seventeen of 19 species discussed had ranges that terminated at latitudes within Michigan or at the borders. Bombinae distribution appeared to be most closely related to rodent distribution, the 70°F July isotherm, rainfall, vegetation, terrain elevation and host distribution for Psithyrus spp. Studies of nests of Bombinae indicated that Acarina were common to all but one of the 27 nests examined. Coleoptera, Lepidoptera, Collembola, Diptera, Hymenoptera and Psocoptera were found in 9 to 18 of the 27 nests. Most of the nests may have been former rodent nests.

Techniques for examining bees for mites were developed and are presented. The techniques for examining bees for internal mites are unique. The help of several authorities (E. W. Baker, J. Camin, E. A. Cross, P. E. Hunter, D. Johnston and E. Lindquist) in determinations of mites is acknowledged. Locustacarus (Bombacarus) buchneri (Stammer) 1951, new combination, is redescribed and discussed in detail. This species has not been previously described from North America. New biological observations on L. buchneri are presented. The relative abundance of Bombinae with mites is highest in April, steadily decreases until August and reaches a second high peak in October. Queens and males in nests were observed

to have a higher percent of infestation with hypopi. This supports the hypothesis that acarid hypopi may be attracted to newly emerged bees in preference to older worker bees in the nest. Additional evidence to support this hypothesis is presented. Queens and males in one nest studied carried 14 of the 15 mesostigmatid mites found on all bees in this nest. One queen Bombus vagans caught at flower had over 859 mites (Scutacarus acarorum and Kuzinia laevis) on the thorax and abdomen. The average numbers of hypopi per anatomical part of 93 nest bees were (1) males, 21.7 (2) workers, 12.8 and (3) queens, 4.5 in one nest studied. The propodeum and abdominal segment I were demonstrated to be the most likely area for occurrence of mites and the area most likely to bear the highest numbers of mites. A check list of twenty-five families of mites found with Bombinae is provided. Distribution records and species associations of mites and bumble bees collected at flower and in nests are presented. The distribution of Pneumolaelaps spp. in North America is discussed and Pneumolaelaps longanalis n.sp. (Acarina: Laelaptidae) is described. The distribution and association patterns of the mites found most commonly on Michigan Bombinae are discussed. Kuzinia laevis and Scutacarus acarorum were found on most Bombinae throughout Michigan. Pneumolaelaps spp., Parasitus sp. and Proctolaelaps spp. occurred with less frequency. Locustacarus buchneri is relatively host specific and is found primarily in air sacs of Bombus bimaculatus. The colonization of nests by mites can be

adequately explained by transportation upon nest material, upon the vertebrate which constructed the nest, upon Bombinae and upon a host of invertebrate invaders of the nest. Michigan mites found with Bombinae range from mites which feed upon decaying leaves in the nest to fungivorous, omnivorous, predaceous and parasitic mites.

MAJOR FINDINGS OF THE STUDY OF ACARINA
ASSOCIATED WITH MICHIGAN BOMBINAE

1. Seventeen of 19 species of Bombinae discussed were found to have ranges that terminate at latitudes within Michigan or at the borders.
2. Bombinae distribution appeared to be most closely related to rodent distribution, the 70°F July isotherm, rainfall, vegetation, terrain elevation and host distribution for Psithyrus spp.
3. Acarina were common to 26 of 27 Bombinae nests studied.
4. Techniques for examining Bombinae for internal mites are unique.
5. Locustacarus (Bombacarus) buchneri (Stammer) 1951 is redescribed and discussed in detail. This species has not been reported from North America. New biological observations on L. buchneri are presented.
6. The relative abundance of Bombinae with mites is highest in April, steadily decreases until August and reaches a second peak in October.
7. Evidence for the hypothesis that acarid hypopi may be attracted to newly emerged bees in preference to older workers is presented.
8. The propodeum and abdominal segment I were demonstrated to be the most likely areas for occurrence of mites and the areas most likely to bear the most mites.
9. Twenty-five families of mites were found with Michigan Bombinae.

10. Distribution records and species associations of mites and Bombinae collected at flower and in nests are presented.
11. The distribution of Pneumolaelaps spp. in North America is discussed.
12. Pneumolaelaps longanalis n.sp. (Acarina: Laelaptidae) is described.
13. Kuzinia laevis (Dujardin) and Scutacarus acarorum (Goeze) were found on most Bombinae throughout Michigan.
14. Pneumolaelaps spp., Parasitus sp., Proctolaelaps spp. and Locustacarus buchneri occurred with less frequency than K. laevis or S. acarorum.
15. Michigan Acarina found with Bombinae range from mites which feed upon decaying leaves in the nests to fungivorous, omnivorous, predaceous and parasitic mites.

APPENDIX

NESTS OF MICHIGAN BOMBINAE

Bombus affinis Cresson

- A. Collected 29 August 1963 in Kalamazoo County, T2S, R11W, S163. The nest was removed from a stack of shingles in a garage, and transferred to a rearing box for 17 days. Mold was taking over the nest so it was placed in a modified Berlese apparatus. Thirty-seven bees were removed. Over 200 mites, 11 Diptera, 27 Lepidoptera, 7 Hymenoptera, 3 Coleoptera, 2 Psocoptera and 1 Collembola came into the alcohol. Maple seed wings and sunflower seeds were found in the nest. It is thought to be formerly occupied by mice.
- B. Collected 10 September 1963 in Kalamazoo County, T3S, R11W, S32. The nest was removed by digging two feet down and six feet laterally in a lawn. It was put into a modified Berlese funnel within an hour after removal. Two hundred and twenty-seven bees were removed. Hundreds of mites, larval Diptera and Coleoptera were collected along with several adult beetles. Many decayed acorns and white oak leaves were found. It is thought that this nest was formerly occupied by a ground squirrel.

Bombus bimaculatus Cresson

- A. Collected 4 August 1965 in Kalamazoo County, T1S, R10W, S32. The nest was removed from a site in a field where bee behavior was being studied. The original site was in a stack of crates four feet above the ground. The

nest was removed from the field and placed in an extraction funnel. Tear gas (chloropicrin) was applied to cotton at the top of the covered funnel to drive the arthropods into an alcohol containing bottle below the funnel. Collembola, Psocoptera, Orthoptera (Blattidae), Hymenoptera (ants), Lepidoptera, millipedes, centipede, Isopoda and many mites were found in the sample. Only a small sample of bees was obtained.

- B. Collected 11 August 1965 in Kalamazoo County, T1S, R9W, S7. The nest was observed in place 5 August to 11 August, then placed in an open top glass funnel balanced on an open jar containing alcohol. No living bees remained in the nest although a male had been flying near the nest earlier on the day the nest was removed. The nest was on the ground under a thin piece of cement. It was two feet from a vine covered, five feet tall cement and stone wall. Spiders, isopods, centipedes, a millipede, pseudoscorpions, a snail, an oligochaete, Homoptera, Thysanoptera, Hymenoptera, Orthoptera, Coleoptera and hundreds of mites were found in the nest. Only a small sample of bees was obtained. No queens remained in the nest.
- C. Collected 7 July 1966 in Lenawee County, T6S, R3E, S34. The nest was removed from beneath a cement slab porch and placed in a modified Berlese funnel. Ninety-five bees were removed. The queen-worker-male ratio was

28-56-11. Only Diptera larvae and mites were found. very little of the outer covering of the nest was obtained due to the difficulty of reaching the nest.

Bombus fervidus (Fabricius)

- A. Collected 1 September 1963 in Kalamazoo County, T2S, R10W, S21. The nest was removed from the boarded eaves of a toolshed six feet above the ground and placed in rearing box for 7 days before transfer to a modified Berlese funnel. Two dead mice (Peromyscus sp.) were found in the nest. Forty four bees were found. Eighty two Lepidoptera larvae, 85 Diptera, 33 Coleoptera, four Siphonaptera, two Collembola, Psocoptera and over 2000 mites were found in the Berlese sample.
- B. Collected 4 September 1963 in Kalamazoo County, T2S, R12W, S1. The nest was removed from the ground where it was located in the circle of a tire under a bale of hay and placed in a rearing box for 27 days. One hundred and forty-six bees were found. Ten Collembola were removed. A few Lepidoptera, many Diptera, Hymenoptera and mites were found in the Berlese sample.
- C. Collected 6 September 1963 in Kalamazoo County, T1S, R9W, S29. The nest was removed from the roof of an abandoned dog house and placed in a modified Berlese funnel. The dog house had been tipped over two days before. Nest material included a lot of leaf litter. One hundred and twenty-six bees were found. Many Lepidoptera larvae and mites were found in the Berlese sample

in addition to Siphonaptera, Coleoptera and Hymenoptera.

- D. Collected 11 September 1963 in Allegan County, T1N, R13W, S34. The nest was removed from a roll of fence wire two feet above the ground and placed in a modified Berlese funnel. Feathers, hair, leaves and a Peromyscus sp. skeleton indicate this was a former mouse nest. Thirty seven bees were found. Collembola (3), Diptera, Coleoptera, Lepidoptera and many mites were found.

Bombus griseocollis (DeGeer)

- A. Collected 4 September 1963 in Kalamazoo County, T4S, R11W, S24. The nest was removed from a burlap bag hanging from a wall in a barn and put in a modified Berlese funnel. Twenty three bees were removed. The small nest was constructed entirely of burlap. Several Psocoptera, Coleoptera and mites were found in the Berlese sample.
- B. Collected 11 September 1963 in Allegan County, T1N, R13N, S27. The nest was collected on the ground in tall grass three feet from a barn and placed in a modified Berlese funnel. Twenty two bees were found. Psocoptera (21), Hymenoptera, Lepidoptera and mites were found.
- C. Collected 7 August 1965 in Lenawee County, T7S, R3E, S3. The nest was removed from a ball of twine on a shelf six feet above the floor in a garage and put in a modified Berlese funnel. Eleven bees were removed from the nest. Several Psocoptera and many Lepidoptera were found.

Bombus pennsylvanicus (deGeer)

- A. Collected 30 August 1963 in Kalamazoo County, T1S, R11W, S18. The nest was removed from a hubcap in an abandoned chicken coop and put into a rearing box for 38 days. The nest became contaminated with ants. No Berlese sample was taken. One hundred and twenty bees were removed. A few mites were removed from bees which were killed on August 31.
- B. Collected 2 September 1963 in Barry County, T1N, R10W, S28. The nest was removed from a haymow in a barn and put in a rearing box for 50 days. Red ants indigenous to the new site set up a colony in the nest. Ants, Psocoptera and larval Lepidoptera were found in the Berlese sample. Forty-six bees were removed. One mite was removed from a bee which was removed from the nest on 30 September.
- C. Collected 3 September 1963 in Kalamazoo County, T1S, R12W, S32. The nest was removed from the seat of an abandoned truck and put into a rearing box for 48 days before transfer to a modified Berlese apparatus. The nest was constructed of cotton, tissue paper and grass. It may be a former mouse nest. The nest contained 23 bees, some with mites. Many Lepidoptera larvae, Diptera and Coleoptera were found in the Berlese sample.
- D. Collected 3 September 1963 in Kalamazoo County, T3S, R10W, S7. The nest was removed from the empty loft of a barn and transferred to a modified Berlese funnel.

The nest was constructed with cotton and a small amount of paper. It is thought to be a former mouse nest. Eighty one bees were collected. Many Lepidoptera and Coleoptera larvae were found in the Berlese sample. Two Collembola and many mites were found.

- E. Collected 4 September 1963 in Allegan County, T1N, R11W, S36. The nest was removed from a roll of glass wool insulating material found in a shed and transferred to a modified Berlese funnel. The small nest contained 42 bees. Many Coleoptera and mites were found in the Berlese sample.
- F. Collected 5 September 1963 in Kalamazoo County, T4S, R11W, S2. The nest was removed from beneath glass wool insulating material and transferred to a modified Berlese funnel. The nest was composed of glass wool and a small amount of leaf litter. Many full honey pots were present but only 30 bees were found. Coleoptera, Lepidoptera, isopods, seventy three Collembola (3 species) and over a hundred mites were found in the Berlese sample.
- G. Collected 5 September 1963 in Kalamazoo County, T3S, R11W, S26. The nest was removed from the ground underneath a pile of boards near a corral. The nest was composed of leaf litter (pin oak) and a small amount of glass wool. One hundred and seventy bees were found. The Berlese sample included spiders, Pseudoscorpiones, Chilopoda, many Acarina, Isopoda, 256 Collembola,

Siphonaptera, Diptera, Coleoptera, Lepidoptera and Hymenoptera (ants).

- H. Collected 6 September 1963 in Kalamazoo County, T1S, R11W, S21. A partial nest was removed from an old car seat in an unused barn and placed in a modified Berlese funnel. A few mites and Lepidoptera larvae were found. Forty seven bees were collected. The nest material was cotton with a small amount of burlap.
- I. Collected 7 September 1963 in Kalamazoo County, T1S, R10W, S8. The nest was removed from beneath floor boards in a barn and put in a modified Berlese funnel. Ninety three bees were removed. Coleoptera, Pseudoscorpiones, Lepidoptera and several mites were found in the Berlese sample.
- J. Collected 9 September 1963 in Kalamazoo County, T1S, R11W, S19. The nest was removed from a rock pile at the edge of a field and placed in a modified Berlese funnel. Sixty three bees were removed. The nest could have been a second year nest as the nest cases below the active ones looked older than one year. The nest was constructed of a very soft plant material. Grasshopper remains and a dead wasp were found in the nest. The Berlese sample contained many diptera larvae (Fannia canicularis Linnaeus), Coleoptera, some Lepidoptera larvae, a pseudoscorpion and many mites.

- K. Collected 9 September 1963 in Kalamazoo County, T4S, R12W, S15. The nest was inaccessible but eighty one bees were obtained. Two bees had mites on them.
- L. Collected 11 September 1963 in Kalamazoo County, T1S, R12W, S17. The nest was removed from its location about two feet above ground in a wood pile and placed in a modified Berlese funnel. Fifteen bees were found. Many Lepidoptera larvae, 138 Collembola, several Coleoptera and mites were found in the Berlese sample.
- M. Collected 12 September 1963 in Kalamazoo County, T1S, R11W, S32. The nest was removed from a drill base on the floor of a garage and placed in a modified Berlese funnel. Eighty three bees were removed from the nest. Ten Collembola, many Coleoptera, a few Diptera, isopods, a centipede and mites were found in the Berlese sample.
- O. Collected 3 August 1963, Kalamazoo County. The nest was originally obtained from a crevice in a rock wall in south Kalamazoo by R. Macomber. He transferred it to a site 9 miles northeast for behavioral experiments. A flat dish of alcohol and glycerine was placed below the open screen under the nest. Several mites and three Collembola were found.

Bombus vagans F. Smith

- A. Collected 7 July 1965 in Barry County, T2N, R8W, S32. The nest was removed from a junked washing machine and placed in an extraction funnel. Tear gas was applied to cotton at the top of the covered funnel to drive

nest inhabitants into a jar of alcohol below. The nest had been disturbed in the days preceding its collection and only one bee remained. Several Diptera larvae, Coleoptera and mites were found in the sample. Many Diptera larvae and hundreds of nematodes were found in the gallon jar in which the nest was transported to the laboratory. After the nest was placed in the funnel, the inside of the jar was washed with alcohol and the jar was closed.

- B. Collected 7 July 1965 in Barry County, T2N, R8W, S32. The nest was removed from the air duct of an abandoned car and placed in an extraction funnel. Tear gas was applied to cotton at the top of the covered funnel. The nest had been disturbed in the days preceding its collection. Gasolene had been thrown on one edge of the nest. Three bees were collected. Coleoptera, Psocoptera and mites were found in the sample.

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