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TABLE OF CONTENTS

Introduction. 1
Acknowledgements. 2
Personnel 2
Records 2
Collecting Chigger Mites. 3
Attached larvae 3
Chigger Sampling. 5
Recovery of Adults. 6
Culture Methods 7
The Mass Culture. 10
Key to Larval Chiggers. 12
Species Accounts. 14

Trombicula
(Eutrombicula)
alfreddugesi 14
batatas. 15
lipovskyana. 15
splendens. 16
(Leptotrombidium)
myotis 17
(Neotrombicula)
autumnalis 17
lipovskyi. 17
locmisi. 18
subsignata 18
sylvilagi. 19
whartoni 19
(Trombicula)
crossleyi. 20
cyros. 20
fitchi 21
gurneyi. 21
hopkai 22
kardosi. 23
montanensis. 23
trisetica. 24
twentei. 24
I. 24
II 25

Euschongastia
criceticola. 25
kardosi. 26
lacerta. 26
lipovskyi. 26
locmisi. 27
peromysci. 27
pipistrelli. 28
setosa 28
#2 Farrell 28
#3 Farrell 29

Neoschongastia
americana. 29

Speleocola
tadaridae. 30

Pseudoschongastia
hungerfordi 30
farneri 31
Walchia
americana 31
Acomatacarus
(*Xenacarus*)
plumosus 32
(*Acomatacarus*)
arizonensis 32
gatti 32
polychaetus 33
sensae 33
Cheladonta
species 31
Leeuwenhoekia
(*Comatacarus*)
americanus 34
Hannemania
species 34
Host-Chigger Lists 35
Habitats of Active Larval Chiggers 47
Chigger-Host Relationships 49
Laboratory Life History Studies 52
Morphological Studies of Postlarval Stages 55
Internal Morphology and Histology of Adults . . . 59
Technical Reports 61

INTRODUCTION

Chiggers or trombiculid mites are vectors of Scrub Typhus and are one of the vectors of Murine or Endemic Typhus, Toxoplasma and possibly Epidemic Hemorragic Fever. Moreover, they are pests of major importance. In spite of these facts, less is known of them than of any other group of medically important arthropods. Although they must be reared to study disease transmission, little was known of their life histories or of rearing techniques when this project began.

A complete study of the trombiculid mites of the central United States was undertaken with the following aims:

1. To conduct life history studies in the laboratory and ecological studies in the field for each species, and to obtain exhaustive biological data with the practical objectives of learning rearing techniques and field ecological relationships.

2. To correlate and describe the various stages for each species and compare the corresponding stages of the available species, so that chigger species can be recognized from any stage obtained in the field.

3. To complete taxonomic studies, describe and name, if necessary, the larvae of each species under investigation, since proper identification is of primary importance, so that other investigations can be correlated.

4. To make complete host lists for all species of chiggers, determining the most important hosts for each species.

5. To study the internal morphology and histology of chigger mites to aid future investigations of disease transmission to the hosts of larval chiggers.

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The Chigger Project sponsored by the O.N.R. at the University of Kansas has received assistance from many people not connected with it. For aid in larval identification we wish to thank Dr. James M. Brennan, Dr. George W. Wharton and Mr. Bernard Greenberg. Dr. E. W. Baker of the United States National Museum loaned important chigger specimens. Many graduate students in the Departments of Zoology and Entomology have contributed vertebrate hosts and chiggers, especially Dr. Maurice F. Baker, Mr. Harold A. Dundee, Mr. Robert E. Elbel, Mr. J. Knox Jones, Jr., Mr. Edward Martin, Mr. Dennis G. Rainey, and Mr. Olin L. Webb. Mr. John W. Twente of the University of Michigan generously sent hosts and and supplied chiggers from south central Kansas. Dr. Cluff Hopla of the University of Oklahoma assisted the project while at the University of Kansas and sent us many specimens of mammals from Oklahoma. Much of the work was conducted on the University of Kansas Natural History Reservation with the constant and generous aid of the Resident Naturalist, Dr. Henry S. Fitch. Staff members and graduate students at the Museum of Natural History, University of Kansas aided in the identification of certain birds and mammals, for which we are grateful. The United States Public Health Plague Suppressive Units generously allowed one of us (Loomis) to work with units for several days in July, 1948 and August, 1949, in northwestern Kansas.

PERSONNEL

The original Principal Investigator of the Navy Chigger Project was Dr. Donald S. Farner, who arranged for the first contract in February, 1947. Dr. H. B. Hungerford took the position after Dr. Farner left the University, until the fall of 1948, followed by the last Principal Investigator, Dr. Charles D. Michener. Dr. E. Raymond Hall worked in cooperation with the Principal Investigators. The first Research Assistant in Entomology was Mr. Louis J. Lipovsky, followed by Mr. D. A. Crossley in June, 1951 and Mr. Ervin H. Kardos in October, 1951, both continuing to January, 1953. Mr. Keith Wolfenbarger was a Research Assistant in the summer of 1950. The first Research Assistant in Zoology was Mr. Robert B. Finley, Jr. who was later aided by Mr. Leonard Koger. Both Zoologists left in June, 1948, and were followed by Mr. Richard B. Loomis, who continued to January, 1953. Many individuals, mostly students at the University of Kansas, have worked as technicians.

RECORDS

It was the practice of the project members to keep notes in the following way. A journal was kept relating to general observations, details of the trips and the habitats, the specimens collected and where, weather, temperature, and other details.

A catalog was kept by each collector* and the specimens were each given a separate number (or a lot number, if the same kind was from the same locality and habitat) which consisted of the initials of the cataloger (usually the collector), the year, month, day, hyphen and a number denoting the number of the specimen (or specimens) for that date. If two or more individuals are listed under a single number, they are listed in parentheses at the end, for example RL520612-2(2). This number keeps all data coordinated. The locality (state, county, miles from the nearest town, and other pertinent information), the date, and collector (if other than the cataloger) are recorded, as well as the field identification of the specimens cataloged, the sex, and frequently measurements (esp. mammals), and apparent age.

The third set of notes (species accounts) were usually kept only on the chigger hosts. Early species accounts gave details on the host only, while later accounts also gave information on the chiggers recovered. Early records of the chiggers recovered were keptseparately on outline sheets with notes on the number of each species and the disposition (preserved, cultured or discarded).

COLLECTING CHIGGER MITES

Three methods were used to collect larval chiggers. The first was to obtain possible vertebrate hosts and to remove attached larvae, the second involved the taking of unengorged active chiggers on Chigger Samplers while the third method, not too successful, involved the placing of samples of soil, wood, bird or mammal nests into funnels over water or alcohol, and driving out the larval and adult chiggers with heat and drying from above. Adults were also taken from under rocks, bark and were washed from the soil.

ATTACHED LARVAE

The first step to obtain attached larvae was to collect the vertebrate host. Amphibians and reptiles were generally collected alive, birds were always shot, while mammals were killed or taken alive by various methods. If proper facilities were available immediately, it was advantagous to collect most amphibians, reptiles and mammals alive. Chiggers on amphibians were usually embedded in the skin, and remained there over long periods of time until they were removed by use of a sharp needle. Reptiles and mammals were individually placed either in a screen cage over a pan which contained a solution of synthetic detergent and water, or were placed on a screen platform over the detergent solution in a wide mouthed jar of appropriate size, capped with a screen lid securely held by a screw band. As the chiggers engorged and detached from the host, they would fall into the detergent solution which, if clean, kept the chiggers (those without trachea) active for several days.

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* L. J. Lipovsky did not maintain a continuous catalog after 1948, his material being cataloged by Loomis. On long field trips, usually only one individual would catalog the specimens to avoid later confusion due to similar field numbers.

Reptiles were kept over the detergent solution for long periods of time with a minimum of difficulty with fecal matter and food. Mammals, however, were more troublesome, and the detergent solution needed frequent changes. Foods were used which did not foul up the water excessively, such as lettuce and carrots. A window screen was also placed beneath to catch feces. Fortunately the attached larvae on mammals engorge and drop off rapidly.

Many of the vertebrate hosts were killed in the field, sometimes hundreds of miles away from the laboratory. These dead specimens were immediately placed individually into plastic bags, along with a field number, with the bag securely sealed. If the specimens would not reach the laboratory for many hours, they were sealed in water-tight jars and placed on ice in a portable icebox. This is absolutely necessary during the summer. A tentative field identification was always made, and was listed in the field catalogue, along with the field number, locality, date, and collector. When brought in from the field, the vertebrates were usually identified by Project members (Finley and Loomis), assisted, if necessary, by the staff of the Museum of Natural History. When the identification was in doubt, or the vertebrates represent important records, specimens were saved after examination (amphibians and reptiles were preserved, skulls and occasionally skins of mammals were saved, while birds usually could not be saved). In the laboratory, the specimens in the plastic bags were placed in the refrigerator (approximately 40°F.) and were kept there one to several days. Following this cooling (to inactivate the attached larvae), the specimen was removed and examined under a binocular dissecting scope to determine the site of chigger attachment. Representatives of chiggers from each area (i.e. ears, legs, belly) were picked off the host by the use of needles and forceps, and were mounted for accurate determination. Also the approximate numbers of each kind together with their location were recorded in the host species account. After warming at room temperature, the specimens were placed in wide-mouth fruit jars of appropriate size, and covered with the solution of synthetic detergent and the plastic bag was washed and examined. The jars were tightly sealed and shaken vigorously several times, over a period of 15 minutes or more. The solution was then poured into a cylinder, after the host was wrung out, and replaced in the jar for one or two more washes. After the material has settled the top scum is stirred up and eliminated, and the wash can be decanted. The material at the bottom of the cylinder is then placed in a petre dish to be sorted under a dissecting scope. After two to three washes the bird or mammal was then re-examined under a dissecting scope to remove any remaining chiggers. (For more information on washing see Technical report, Lipovsky 1951:151-156). The chiggers were then taken from the mass of debris and were placed in Syracuse Watch Glasses, always accompanied by the field number. The chiggers were then sorted as to size, color, shape, etc. and were determined to species by identification of mounted specimens. The unengorged larvae were usually preserved in Ethyl Alcohol (75-85%). The engorged larvae were then carefully sorted (see Key to engorded larvae) and if they are suitable and desired for culturing, typical representatives were mounted and identified and others were cultured. (See culture notes for more details).

CHIGGER SAMPLING

A convenient and successful device for securing active unengorged larvae has been the Chigger Sampler, modified at Kansas from the earlier devices used at Duke University (Wharton, 1952:107). It is a thin black plastic rectangular plate (3 X 69 X 139 mm.), cut from sheets of Plexiglas-Acrylic plastic. The weight of each plate is approximately 39 grams, and the size of the surface is approximately one-tenth of a square foot. This size is convenient to carry and to drop into a wide-mouth fruit jar containing alcohol or detergent-water solution when large numbers of active larvae are present. It also facilitates rapid calculation of the chigger per square foot. The samplers are heavy enough to lie flat in open areas and will stay in position among grass and leaves, if pressed down slightly when placed into position. The black opaque surface casts a strong shadow, which seemed to activate and direct the larvae, and afforded an excellent background on which to observe them easily. It was inconvenient to carry more than a few wide-mouth fruit jars containing liquid, so we used a fine camels hair brush to pick up the larvae. Only when large numbers were present and all were to be collected, were the fruit jars used.

The success of the sampler depended upon the ability of the worker to place it in the proper place at the proper time. Our early investigations in the summer revealed only the common pest chigger, Trombicula alfreddugesi. Later work in low moist valleys uncovered T. lipovskyana. Continued sampling in the woods and woodland edge turned up T. sylvilagi in the fall, while early winter and early spring sampling resulted in the discovery of T. lipovskyi and Euschongastia # 3. One engorged larva of E. loomisi crawled upon a sampler in late fall. Sampling in the dry open areas among tall-grass, weeds and open forest floors revealed the summer 'bird' chigger, Neoschongastia americana, found only after mounting many samples since they closely resemble T. alfreddugesi on the sampler. One of the common spring, summer and fall chiggers T. gurneyi, continued to elude us until we re-examined the host data and found that within the University of Kansas Natural History Reservation area the chigger larvae were restricted to woodland species. Since we had not found them in many samples of the forest floor, we turned to sampling logs which were in an advanced stage of decay and found the larvae exceedingly common at certain times of the year and under proper temperature conditions (relatively cool compared to T. alfreddugesi). Later sampling revealed T. gurneyi to be common around decaying upright trees and under decayed logs where 'frass' is present, within the deciduous forests. (See Key to unengorged larvae for field recognition characters). This makes a total of eight species taken on samplers within an area of one square mile, more species probably than the total reported from the rest of the world taken by comparable methods. This also represents seven of the ten most common chigger species taken on or near the Reservation. The failure to uncover the other common species is certainly due to our failure to sample in the correct place at the proper time. The rarer species certainly will be difficult to track down since even the vertebrate hosts only occasionally pick them up. The three common species not yet sampled are; Hannemania a frog chigger, certainly found in moist situations; Pseudoschongastia hungerfordi,

a tiny white, slow-moving chigger probably restricted to underground burrows and nests, since they seem to require a great deal of moisture in the larval stage, and the third, Euschongastia peromysci, which is a woodland species and probably is found around logs, stumps and the forest floor, near rodent nests and runs. Many species (e.g. T. cynos, T. trisetica, and Walchia americana) seem to appear suddenly in great numbers on the hosts and drop off rapidly leaving only occasional attached stragglers.

Examination of nests by the Berlese funnel method have revealed remarkably few larvae, either engorged or unengorged. This is surprising since most mammals spend a great deal of time in their nests and the nests especially of the wood rat seems to afford an excellent habitat with abundant arthropods which could serve as food for the postlarval stages. Two explanations are given tentatively. First, our methods to recover larvae from the nests probably are not correct (Berlese method, heat and light over the nest) and second, the larvae probably go through the nest material into the surrounding soil or other material which affords protection for the delicate eggs and postlarval stages.

KEY TO UNENGORGED LARVAE, AS OBSERVED ON CHIGGER SAMPLERS AT THE UNIVERSITY OF KANSAS NATURAL HISTORY RESERVATION.

1. a) Size large*, color bright orange to bright red - - - - - - 2
   b) Size small, color white, movement slow - - -Trombicula gurneyi

2. a) Color red, movement rapid - - - - - - - - - - - - - - - - - 3
   b) Color red to orange 'hairy', movement slow - - - - - - - - 4

3. a) Movement direct, legs appear coordinated - T. (Eutrombicula)
   b) Movement erratic, legs appear wobbly - - - Neoschongastia

4. a) Color dark red - - - - - - - - - - - - - - - - T. (Neotrombicula)
   b) Color orange, pale, 'hairy' appearance - - Euschongastia # 3

RECOVERY OF ADULTS

We have found nymphs and adults commonly beneath the bark on rotten logs to the south (T. splendens), and T. alfreddugesi is very commonly uncovered under rocks in the spring while the soil and rocks are cool. Deeper in decaying logs we have found T. gurneyi. Six adults of T. alfreddugesi were found in a nest of the skink, Eumeces fasciatus. These adults almost certainly developed from larvae that dropped from the female skink which remained with the eggs for several weeks. The soil was tightly packed within the nest, but numerous cracks afforded safe shelters for the adults, and the maintainance of moisture by the female skink for her eggs was advantageous.

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* Size based upon large (Eutrombicula) larvae which are common throughout the summer.

Nymphs and adults of T. alfreddugesi and T. lipovskyana were also recovered from the soil, by emersing sod in a large container of warm water, breaking up the material thus allowing the nymphs and adults to float to the surface.

The larvae, as well as nymphs and adults, were mounted on slides in Polyvynol-alcohol medium (see technical report, Lipovsky, 1953:42-44) and covered with number one cover glasses.

CULTURE METHODS

The development of culture methods for chiggers was undertaken in consideration of two aims: To provide not only methods for detailed life history studies, but also to develop methods which would enable other workers to culture these mites for studies in disease transmission, morphology, histology, taxonomy, and other fields. The methods and equipment described herein have been used primarily for life history studies, (but may be easily modified to suit other types of work). The mass culture is of particular significance to disease transmission studies.

The culture tube and dish used for life history studies have been described in detail elsewhere (Lipovsky, 1953:4-7)

Collembolans (Sinella) and their eggs (see Lipovsky, 1951) have proved to be the most convenient food for use in culturing the post-larval stages. Other insect and arthropod eggs have been used, but the ease of maintenance of the Collembola colonies in the laboratory and the constant supply of acceptable food thus provided are distinct advantages not associated with other possible food sources. The Collembola colonies are kept in finger bowls or larger stacking dishes which are lined with the charcoal-plaster of Paris mixture. Pellets of dried yeast are added as food; water is added to preserve the necessary humidity.

An outline of the culturing procedure usually followed is given in the following paragraphs. As explained subsequently, it is sometimes desirable or necessary to deviate from this procedure; however, this general method is followed in the majority of cases.

The engorged larvae are usually removed from the host by picking or by the washing method, or are recovered from a detergent-water solution in the pans beneath the live host. The larvae in detergent in watch glasses are then carefully sorted under the highest power possible on dissecting microscope and separated into species according to size, shape, color of eyes and body, sensillae etc. as well as possible. The unengorged specimens are preserved and mounted, while the different species to be cultured are determined by mounting engorged individuals which appear representative in every way of that group of larvae.

While there are usually only a few species on a single host individual, we have frequently found that two closely related species (e.g. T. alfreddugesi and T. lipovskyana) occur together and are impossible to separate for culture purposes. The presence of two such species is usually discovered by mounting a series of

larvae for determination. If only one species is represented in the sample, it is fairly safe to consider that the culturing specimens represent one species.

These larvae are then transferred with a pipette from the detergent solution to the culture tube. The plaster lining will absorb several drops of water, but it is advisable to transfer as many chiggers in as few drops as possible; excess moisture greatly facilitates the growth of mold. Up to 50 larvae can be safely cultured in a 5-dram vial. The stopper is replaced and the vial numbered.

Periodically (usually every 48 hours) the vial is checked to determine the progress of the mites. The larvae frequently remain active for 4 to 5 days, but soon become quiescent and enter the prenymph stage. Occasionally, active larvae move to the top of the vial and are found on the cap when the vial is opened; these larvae are returned to the vial with a needle.

When the nymphal forms begin to emerge, these are carefully examined and gross appearance is noted. Since the nymphs frequently climb the sides of the vial and stopper, it is advisable to rap the vial sharply on the table several times before opening. No injury will be done to the mites if the tube is free from debris. Food (Collembola eggs) is added and the feeding habits are noted if observed. Representative nymphs are preserved for study 3 to 4 days after emergence; the time interval allows sclerotized structures to harden properly so that the specimens are truly representative. After feeding and after a sufficient time interval, the nymphs become quiescent and enter the preadult stage.

During the preadult quiescence, or after emergence of the adults, the mites may be trasferred from the culture tube to a culture dish. Grooves are cut in the plaster lining of the dish, so that the adults are provided a place for hiding and ovoposition. Collembolans are added to the dish, and pellets of dried yeast are introduced as food for these insects. Since the dish is more subject to evaporation than is the tube, water must be added at frequent intervals.

Maintenance of the adults in the dish until eggs are laid may become a matter of several months. During this time the humidity in the dish, the yeast for the collembolans, the egg production of the collembolans, and the number of collembolans present are the important factors in development of a successful culture (temperature in our laboratory was controlled at approximately 70°F). The egg production of the collembolans can be kept relatively high if adequate mold-free food is provided, and the collembolans themselves may be easily killed and removed if they become too numerous.

After chigger eggs are deposited in the grooves of the dish, it becomes important to insure a plentiful supply of collembola eggs; adult chiggers will eat their own eggs in the absence of other food. Frequently either the adults or the eggs are transferred to a separate dish to insure unmolested development.

If careful notes are taken during frequent inspections and representative forms of the various stages are preserved for more detailed study, an accurate record of the life history of the mite under laboratory conditions is acquired.

Several modifications of this culture method are employed in special cases. As explained below, these are generally modifications in technique to resolve specific difficulties rather than modifications in equipment.

Several of the smaller species of trombiculids, for example Walchia americana, Pseudoschongastia farneri and hungerfordi, and Trombicula trisetica, escape from culture dishes far more readily than do the larger species. For this reason it has been found advisable to dispense with the culture dish and retain the adult mites in the culture tube. Thus, the entire life history is carried out in a single tube. Since observations are somewhat impeded by the relatively poor lighting in the tube, the entire contents are occasionally knocked from the tube into a petri dish; the number of mites and the stages present are noted and then returned to the tube. The number of collembolans is also controlled in this manner.

A second modification concerns observations on the food and feeding habits of the postlarval mites. Collembolans are customarily introduced into the culture dish with the mites; in these instances feeding observations are rarely made and it is difficult to determine the nature or amount of food taken. If, instead of adding the collembolans, only the eggs of these insects are placed in the culture dish, observations of feeding are more frequent. Moreover, an estimate of the amount of food required and of the type of food preferred (whether egg or active stage) is obtained. The additional time required in maintaining cultures by this method is well worth the information thus gained.

An important consideration in life-history studies is accurate identification of the species of chigger mite under investigation. At present the species can be positively identified only from the mounted larva. Since more than one species is commonly found on a host animal, and as these usually cannot be completely separated before being placed in culture tubes, correlation of postlarval stages with larval forms frequently becomes a major problem. Of course larvae may be obtained from female mites and the female thus identified, but many cultures cannot be carried to this stage.

The species can be identified from the larval skin discarded by the nymph, if this skin can be found. To facilitate the location of the cast larval skin, "isolation" tubes are used. These are 1 dram glass vials partially filled with the charcoal-plaster-of-Paris mixture, and stoppered with a cork. The sides of the vial are not lined with plaster and thus allow inspection without removal of the stopper. Engorged larval mites are placed in a regular culture tube; when these larvae become inactive and enter the prenymph stage they are placed individually in the "isolation" tubes. When the active nymphs emerge, the cast larval skin is easily located and mounted, and an accurate identification of the individual nymph is obtained and the nymph is placed in a regular culture tube or dish.

One difficulty yet to be overcome is the presence of cheese-mites (family Acaridae) as contaminants in Collembola cultures and in chigger cultures containing these insects. Acarid mites feed on the yeast provided for the collembolans; they multiply rapidly and cover the surface of the yeast (pellets) in 1 to 2 days. Their presence inhibits egg production by the collembolans; also, hypopal stages of these mites attach to both the collembolans and the trombiculids but apparently do little harm. Cheese-mites may become so numerous that the culture dish must be abandoned, and the trombiculid mites transferred to a fresh dish. A partial control of these contaminant mites may be effected by providing only the amount of yeast that the collembola will consume. Obviously, this amount is hard to determine; too little yeast will restrict the egg production of the collembolans as much as the presence of the acarid mites. Yeast pellets should be scattered widely over the surface of the dish and not concentrated in one pile, to allow the collembolans better access to them. Feeding the collembolans in this manner every 48 hours, and then removing the uneaten yeast several hours later, gives an adequate but not complete control.

THE MASS CULTURE

The mass culture was developed as a means of providing large numbers of postlarval mites for various additional studies; larvae are also periodically produced. This culture method is excellent for keeping a chigger species alive in the laboratory over long periods of time. The principal advantage of this method is the slight amount of attention necessary for maintenance.

The procedure for establishing the mass culture is as follows:

1). A medium sized terrarium (15 x 9 x 9 inches used in our laboratory) is filled to a depth of 1 to 2 inches with decayed wood which has been autoclaved to kill possible contaminating arthropods and molds.

2). Into this terrarium are placed a host with attached larvae or engorged larve of the desired species, either washed from their host or taken from detergent solution in a pan below the host. A number of collembolans are introduced and pellets of yeast are added.

3). During the time required for the adult stage to be reached and eggs laid (usually 6 to 7 weeks), the culture is periodically checked; enough water is added to keep the substratum moist and yeast pellets for the collembolans are replaced when exhausted.

4). When larvae begin to appear (their presence is easily detected with chigger sampler) a vertebrate host animal, preferably a lizard or small snake is introduced in the culture, so that the larvae can engorge and drop off.

5). Continued maintenance of the culture requires only periodic addition of water to maintain the humidity, yeast as food for the collembolans, and occasional feeding of the snake or lizard.

The mass culture thus furnishes a year-round supply of adults (for experimental purposes) and a periodic supply of larvae. Although maintained in the laboratory at a constant temperature, the larvae appear periodically during approximately the same seasons as is found in the natural state; i. e., larvae of summer chiggers are present in the mass culture during the late spring, summer, and early fall, but are absent during the late fall and winter months.

Mass cultures of the common pest chigger, Trombicula (Eutrombicula) alfreddugesi, and its relative, T. (E.) splendens, have been maintained in our laboratory for two years; the latter culture is still existent. However, mass cultures can no doubt be prolonged for greater periods than two years.

KEY TO THE LIVING ENGORGED LARVAL CHIGGERS (FAMILY TROMBICULIDAE) FROM NORTHEASTERN KANSAS, AS OBSERVED UNDER A BINOCULAR DISSECTING SCOPE.

1. a) Larvae embedded in the skin of amphibians (size large, red) - Hannemania
   b) Larvae not embedded in the skin of amphibians- - - - - 2

2. a) Size large*, (500u or more in length)- - - - - - - - - 3
   b) Size small (400u or less in length)- - - - - - - - - - 9

3. a) Color deep red to deep orange - - - - - - - - - - - - - 4
   b) Color pale orange, yellow to white - - - - - - - - - - 6

4. a) Distinct 'shoulders', narrow termination of body, sensillae globose- - - - - - - - - - - - - - - - - Neoschongastia
   b) No distinct shoulders- - - - - - - - - - - - - - - - - - 5

5. a) Sensillae globose, round, gnathosoma under body - Euschongastia setosa
   b) Sensillae flagelliform, usually longer than wide, gnathosoma not under body- - - - - - - - - - - - - - - - 6

6. a) More than one mastitarsala and other flagelliform setae on leg III. Color orange. (Mostly winter, October-April) - - - - - - - - - - - T. (Neotrombicula) (3 ssp.)
   b) One mastitarsala and no other flagelliform setae on leg III. Color deep red to orange. (Summer, May-October) - - - - - - - - - - - - -T. (Eutrombicula) (2 ssp.)

7. a) Body appears setose ('hairy'), pale orange to white, sensillae globose, Euschongastia. - - - - - - - - - - - 7
   b) Body appears nude, pale orange to white, sensillae flagelliform, slightly smaller than T. (Eutrombicula) (summer, April-November) - - - - - - - -Trombicula gurneyi

8. a) Color pale orange- - - - - - - - - - - -E. peromysci and E. #3
   b) Color white- - - - - - - - - - - E. # 2, E. loomisi and E. pipistrelli (On bats, E. pipistrelli)

9. a) Color dark brown, orange to bright yellow - - - - - - - 10
   b) Color white (occasionally pale yellow) - - - - - - - - 13

10. a) Size medium small, round, orange to brownish - - - - - 11
    b) Size small, elongate orange to round yellow- - - - - - 12

11. a) Body globose, gnathosoma under body, color brown, sensillae globose- - - - - - - - - - - - - - - - - - Cheladonta
    b) Body with gnathosoma anterior, not under body, sensillae flagelliform - -Trombicula [illegible] T. fitchi and T. kardosi

*The basis of size is the large red engored Trombicula (Eutrombicula) the common summer chigger and the red T. (Neotrombicula) the common winter chigger. Size over 500μ in length.

12. a) Body elongate, color orange (Summer) -*Trombicula trisetica*
    b) Body round to slightly elongate, color yellow (Winter) - - - - - - - - - - - - - - - - - -*T. cynos*

13. a) Size very small, round, white to pale yellow - *Walchia americana*
    b) Size small, elongate, narrow body *Pseudoschongastia* - - 14

14. a) Eyes bright red, mostly eastern - - - - *P. hungerfordi*
    b) Eyes pale pink to white, mostly western - - *P. farneri*

SPECIES ACCOUNTS

Trombicula (Eutrombicula) alfreddugesi (Oudemans)

Geographic distribution.--South and Central America northward to Canada (Ontario), North Dakota and east to the Atlantic coast, westward in the United States to the Rocky Mountains, in Colorado, locally to California. In Kansas, it is statewide and extremely common.

Seasonal occurrence.--In northeastern Kansas it appears the last of May, and disappears from the hosts in November. Chigger samplers have taken them only up to October. Extremely abundant in June, July, August and September.

Ecology.--This is the most widespread summer chigger, and has been taken on almost every terrestrial vertebrate collected during the larval active season. It is particularily abundant in the grasslands and woodland edge, becoming less common to absent in the climax deciduous forests. It seems to be able to survive under drier conditions than either T. splendens or T. lipovskyana, both of which occur within the geographic range and overlap almost entirely in habitat preference. Adults are commonly found under limestone rocks along prairie ledges in late spring (May) in Kansas. Rarely, if ever, are adults of this species found under the bark of decaying logs in a forest habitat. Adults have been washed from the soil in different grassland habitats.

Life history.--This species was reared from larva to larva on numerous occasions. Duration of prenymphal stage, 6-13 days; duration of nymphal stage, 15-120 days; duration of preadult stage, 13 days; duration of adult stage prior to oviposition, 7-27 days; duration of egg stage, 7-9 days; duration of deutoval stage, 6-9 days. Total time from engorged larva to unengorged larva, 49-191 days. Food preferred: Eggs, although active stages are occasionally eaten.

See Technical Report Wolfenbarger 1953, for additional information on this species.

Hosts.--Amphibia: Bufo woodhousii, Acris gryllus and Rana pipiens.

Reptilia: Terrapene ornata, Holbrookia maculata, Sceloporus undulatus, Phrynosoma cornutum, Crotaphytus collaris, Ophisaurus attenuatus, Cnemidophorus sexlineatus, C. sackii, Eumeces fasciatus, E. obsoletus, Urosaurus ornatus, Uta stansburiana, Diadophis punctatus, Coluber constrictor, Masticophis flagellum, Elaphe guttata, E. obsoleta, Heterodon nasicus, H. platyrhinos, Sonora episcopa, Pituophis catenifer, Lampropeltis calligaster, Lampropeltis getulus, L. triangulum, Natrix erythrogaster, N. rhombifera, N. sipedon, Thamnophis radix, T. sauritus, T. sirtalis, Tropidoclonion lineatum, Agkistrodon contortrix, Crotalus horridus, C. viridis.

Aves: Buteo jamaicensis, Tympanuchus cupido. Colinus virginianus, Rallus elegana, Zenaidura macoura, Coccyzus americanus, Crotaphaga sulcirostris, Melanerpes erythrocephalus, Eremophila alpestris, Cyanocitta cristata, Corvus brachyrhynchos, Parus

bicolor, Troglodytes aedon, Thryothorus ludovicianus, Toxostoma rufum, Sialia sialis, Turdus migratorius, Sturnus vulgaris, Passer domesticus, Icterus galbula, Molothrus ater, Quiscalus quiscula, Sturnella magna, S. neglecta, Piranga rubra, Richmondena cardinalis, Spiza americana, Pipilo erythrophthalmus, Calamospiza melanocorys, Chondestes grammacus, Spizella passerina, and S. pusilla.

Mammalia: Didelphis marsupialis, Cryptotis parva, Myotis velifer, Tadarida mexicana, Sylvilagus floridanus, Sciurus niger, Cynomys ludovicianus, Citellus tridecemlineatus, Perognathus flavescens, Perognathus hispidus, Dipodomys ordii, Onychomys leucogaster, Reithrodontomys megalotis, R. fulvescens, Peromyscus maniculatus, P. leucopus, Sigmodon hispidus, Neotoma floridana, N. micropus, N. albigula, N. cinerea, N. mexicana, Microtus pinetorum, M. ochrogaster, Rattus norvegicus, Mus musculus, Canis latrans, Canis familiaris, Procyon lotor.

Trombicula (Eutrombicula) batatas (Linnaeus)

Geographic distribution.--South and Central America, northward to Texas, Alabama, Georgia, Florida, California and southwestern Kansas (Seward County).

Seasonal occurrence.--Larvae were collected in Kansas on September 9.

Ecology.--In Kansas the larvae were taken from hosts obtained at a single locality, in a sand-sagebrush habitat in the Cimmaron River valley.

Life history.--This species was not cultured.

Hosts.--Aves: Sturnella neglecta, Mammalia: Perognathus hispidus and Dipodomys ordii.

See technical report Wolfenbarger, 1953, for further details.

Trombicula (Eutrombicula) lipovskyana Wolfenbarger

Geographic distribution.--Western Tennessee (Henderson County), Arkansas (Pope and Washington counties), eastern Oklahoma (Delaware County) and eastern Kansas (Anderson, Bourbon, Douglas, Leavenworth, Montgomery, and Shawnee counties, doubtfully from Logan County in western Kansas)

Seasonal occurrence.--June 12 to November 5 in Douglas County, Kansas.

Ecology.--This species occurs in the same general areas as the common chigger T. alfreddugesi. The species lipovskyana seems to be restricted to moist areas either in meadows or woodlands, usually in valley habitats, commonly near swampy areas. Birds seem to be commonly infested, but the small mammals of the moist areas are commonly infested. Larvae have been sampled in several areas of Douglas County

Life history.--This species was reared in culture along with Trombicula (Eutrombicula) alfreddugesi. The only observed values which definitely pertain to this species are the duration of the eggs stage (30 days) and the duration of the deutoval stage (8 days). Otherwise the life history is probably similar to that of T. (E.) alfreddugesi.

Hosts.--Amphibia: Acris gryllus. Reptilia: Terrapene ornata, Crotaphytus collaris, Eumeces obsoletus, Coluber constrictor, Elaphe obsoleta, Lampropeltis getulus, Thamnophis sirtalis, Agkistrodon contortrix, and Crotalus horridus. Aves: Tympanuchus cupido, Colinus virginianus, Rallus elegans, Bartramia Zenaidura macroura, Tyrannus tyrannus, Empidonax ?, Parus bicolor, Troglodytes aedon, Toxostoma rufum, Sialia sialis, Turdus migratorius, Sturnus vulgaris, Passer domesticus, Agelaius phoeniceus, Molothrus ater, Quiscalus quiscula, Sturnella magna, Sturnella neglecta, Richmondena cardinalis, Spiza americana. Mammalia: Sylvilagus floridanus, Sciurus niger, Sigmodon hispidus, Microtus ochrogaster, Cryptotis parva, Neotoma floridana, Canis familiaris, and Scalopus aquaticus.

See technical report Wolfenbarger, 1953, for further details.

Trombicula (Eutrombicula) splendens Ewing

Geographic distribution.--Minnesota eastward to Massachusetts, southward through Florida, westward to Texas, Kansas (Miami County), and Nebraska (Saunders County).

Seasonal occurrence.--In Kansas, taken only as adults in May. Larvae were taken in Nebraska and Missouri during August and September.

Ecology.--This species of chigger is a common pest in southeastern states, but is seemingly restricted to moist areas in the western part of its range. Adults are common in Miami County, Kansas under bark of decaying logs in heavy deciduous bottomland and hillside forests. Adults were also frequently taken from under bark of decaying logs in the gulf coastal plain region of Oklahoma, Texas and Arkansas.

Life history.--Reared in the laboratory from engorged larva to newly-hatched larva on several occasions. Duration of prenymphal stage, 6-13 days; duration of nymphal stage, 15-25 days; duration of preadult stage, 6 days; duration of adult stage prior to oviposition, 8-30 days; duration of egg stage, 7-9 days; duration of deutoval stage, 6-9 days; total lapsed time, larva to larva, 48-92 days. Food preferred: Eggs.

Hosts.--Reptilia: Thamnophis sirtalis. Aves: Toxostoma rufum, Pipilo erythrophthalmus and Chondestes grammacus. Mammalia: Reithrodontomys fulvescens and Microtus ochrogaster.

See technical report, Wolfenbarger, 1953, for further details.

Trombicula (Leptotrombidium) myotis Ewing

Geographic distribution.--Maine (Piscataquis County), Pennsylvania (Monroe County), Montana (Ravalli County), Alberta, Canada, Kansas (Barber County), Oklahoma (Cleveland County), Arkansas (Polk County), and New Mexico, and Missouri (Boone County).

Seasonal occurrence.--Pennsylvania (May), Kansas, (August), Arkansas, (March), Oklahoma, (January and April), Missouri (March).

Ecology.--This species was originally described from a bat, and has been recorded several other times from bats. However, we have taken it several times on ground dwelling mammals, and Brown and Brennan (1953:) report it from Alberta on Peromyscus leucopus.

Life history.--This species was not cultured.

Hosts.--Mammalia: Sylvilagus floridanus, Myotis lucifugus, Eptesicus fuscus, Peromyscus leucopus, Neotoma micropus.

Trombicula (Neotrombicula) autumnalis (Shaw)

Geographic distribution.--Europe, United States in southwestern Colorado (Dolores County), southwestern Nebraska (Dundy County) and south central Georgia (Lowndes County).

Seasonal occurrence.--Colorado, 18 October; Nebraska, 1 November, Georgia, 11 December.

Ecology.--Larvae were taken in Nebraska on hosts collected in a marsh, wet meadow habitat. In Colorado, the specimens were found on Neotoma cinerea, which was trapped near its nest.

Life history.--This species was not cultured.

Hosts.--Mammalia: Reithrodontomys megalotis, Neotoma cinerea, Microtus ochrogaster, Microtus pennsylvanicus.

See technical report, Kardos, 1953 for additional information.

Trombicula (Neotrombicula) lipovskyi Brennan and Wharton

Geographic distribution.--Northwestern Kansas (Norton County) to southeastern Nebraska (Richardson County) southeastward to Missouri (Pike and Stoddard counties), and Arkansas (Polk County), and west to Oklahoma (McClain County).

Seasonal occurrence.--In northeastern Kansas, it has been taken from October 7 to April 27.

Ecology.--This seems to be a grassland species, invading the sparse forests and forest-grassland ecotone in the eastern part of its range. Larvae have been taken on chigger samplers at the woodland edge. The most important host is Sylvilagus floridanus.

It is a winter chigger, which reaches maximum larval abundance in late November and early December in northeastern Kansas. See technical report, Kardos, 1953, for more details.

Life history.--Reared to the adult stage in the laboratory. Duration of prenymphal stage, 21-47 days; duration of nymphal stage, 15-43 days; duration of preadult stage, 10-16 days. Food prepared: Eggs. See technical report Kardos, 1953, for more details.

Hosts.--Aves: Asio otus, Centurus carolinus, Parus atricapillus, Sturnella neglecta, Richmondena cardinalis and Melospiza melodia. Mammalia: Didelphis marsupialis, Blarina brevicauda, Lepus californicus, Sylvilagus floridanus, Sciurus carolinensis, S. niger, Reithrodontomys megalotis, Peromyscus maniculatus, P. leucopus, Sigmodon hispidus, Neotoma floridana, Neotoma micropus, Microtus ochrogaster, M. pinetorum, Mus musculus, and Canis latrans.

Trombicula (Neotrombicula) loomisi Kardos

Geographic distribution.--Extreme eastern Colorado (Yuma County) and southwestern Nebraska (Dundy County).

Seasonal occurrence.--1-2 November.

Ecology.--This species was taken from hosts trapped in meadows adjacent to streams which flowed through sandy valleys. The almost uniformly unengorged condition indicated that the larval emergence was probably just beginning.

Life history.--This species was not cultured.

Hosts.--Mammalia: Reithrodontomys megalotis, Peromyscus maniculatus and Mus musculus.

See technical report, Kardos, 1953, for additional information.

Trombicula (Neotrombicula) subsignata Brennan and Wharton

Geographic distribution.--Montana (Ravalli County), south to Colorado (Boulder County), North Dakota, Missouri (Taney County), Pennsylvania and New York. Also recently found in California (Marin County).

Seasonal occurrence.--Missouri, 7 September, Colorado 6-15 August, and California, 1 June.

Ecology.--The specimens from Marin County, California, were taken from lizards, Sceloporus occidentalis, and they were engorged. The lizards were obtained from rock piles.

Life history.--This species was not cultured.

Hosts.--Reptilia: Sceloporus occidentalis. Aves: Capella gallinago. Mammalia: Citellus lateralis, Zapus princeps.

Trombicula (Neotrombicula) sylvilagi Brennan and Wharton

Geographic distribution.--Central Illinois (Piatt County) and northeastern Kansas (Jefferson, Leavenworth, Douglas and Miami counties).

Seasonal occurrence.--August to December (see Kardos, 1953).

Ecology.--This species seems to be restricted to sparse woods and woodland-grassland ecotone, especially in the vicinity of limestone outcroppings. Larvae have been chigger sampled at the University Kansas Natural History Reservation. Only unengorged larvae were found on snakes.

Life history.--Unengorged larvae were fed upon a juvenile mouse and successfully engorged and reared to the preadult stage. Duration of prenymphal stage, 14-17 days; duration of nymphal stage, 18 days. (See also technical report Kardos, 1953).

Hosts.--Reptilia: Coluber constrictor, and Agkistrodon contortrix. Aves: Colinus virginianus, Turdus migratorius, Richmondena cardinalis, and Junco hyemalis. Mammalia: Cryptotis parva, Sylvilagus floridanus, Sciurus (niger and carolinensis), Peromyscus maniculatus, P. leucopus, Neotoma floridana, Microtus ochrogaster, Mus musculus, and Zapus hudsonius.

Trombicula (Neotrombicula) whartoni Ewing

Geographic distribution.--Southwestern Nebraska (Dundy County), Kansas (Nemaha to Miami counties), Illinois to Pennsylvania, southward to Florida, Mississippi and westward to Arkansas (Miller and Polk counties) and Oklahoma (McCurtain and Adair counties).

Seasonal occurrence.--In Kansas and Missouri, larvae have been taken from October 12 to January 28, while in Arkansas, it has been taken in March 3 to 29.

Ecology.--This species is closely related to Trombicula lipovskyi, and inhabits the same geographic range in eastern Kansas, Missouri and Arkansas. The two species, however, are separated ecologically, with T. whartoni living in the non-parasitic stages in moister situations, usually forests. The locality in southwestern Nebraska (Dundy County) is unique in lacking the usual deciduous forest habitat, but does have wet meadows which are supplied by springs the entire year. This area also supports typical eastern mammals. T. whartoni is not common in northeastern Kansas, and disappears in December from the hosts. The explanation for this may be the lack of moisture causing the eggs to dry and not hatch. See Kardos, 1953, for more details.

Life history.--Reared to the nymphal stage (duration of prenymphal stage, 22-27 days). Food preferred: Eggs.

Hosts.--Aves: Cyanocitta cristata, Parus bicolor, Richmondena cardinalis, Junco hyemalis, Zonotrichia albicollis and Zonotrichia querula. Mammalia: Sylvilagus floridanus, Sciurus carolinensis, S. niger, Reithrodontomys fulvescens, Peromyscus maniculatus, P.

leucopus, Sigmodon hispidus, Neotoma floridana, Microtus ochrogaster, M. pinetorum, M. pennsylvanicusm, Mus musculus.

See technical report, Kardos, 1953 for additional information.

Trombicula crossleyi Loomis

Geographic distribution.--South central Kansas (Barber County) and southern Oklahoma (Comanche County).

Seasonal occurrence.--May (Oklahoma), July, September and October (Kansas).

Ecology.--Larvae have been taken from hosts living in rocky canyon areas, as well as in sparse woods along the canyons and in nearby sandy valleys. The frequent presence of larvae on the red-headed woodpecker indicates that the postlarval stages may be found in upright dead trees or in cavities of living trees. Deep crevices in canyon walls also may afford a possible habitat.

Life history.--This species was reared from larva to larva in the laboratory. Duration of prenymphal stage, 7-8 days; duration of nymphal stage, 7-31 days; duration of preadult stage, 10 days; duration of adult stage prior to oviposition, 164 days; duration of egg stage, 8 days; duration of deutoval stage, 11 days; total time, engorged larva to newly-hatched larva, 209-234 days. Food preferred: Eggs.

Hosts.--Aves: Melanerpes erythrocephalus, Mammalia: Peromyscus maniculatus and Peromyscus leucopus.

Trombicula cynos Ewing

Geographic distribution.--New York (Tompkins County), Kansas (Douglas, Miami, and Barber counties), Oklahoma (Cleveland, McCurtain, and Comanche counties), Arkansas (Polk County), and California (Plumas County).

Seasonal occurrence.--October to May is the known season range of this species.

Ecology.--This species probably inhabits woodlands, and may be partial to rotten logs and decaying upright trees. Records from Barber County, Kansas, were from bats, Myotis velifer, collected in a gypsum cave.

Life history.--This species was not cultured.

Hosts.--Mammalia: Sylvilagus floridanus, Myotis velifer, Sciurus carolinensis, Sciurus niger, Peromyscus maniculatus, Neotoma floridana.

Trombicula fitchi Loomis

Geographic distribution.--Illinois (Piatt County), and Kansas (Douglas, Miami and Barber counties).

Seasonal distribution.--This species has been taken from September to April in Kansas.

Ecology.--In the eastern part of its range, the larvae have been found only on hosts which are principally arboreal. This seems to indicate that this species is restricted to the nests of squirrels, situated in decaying trees or some other place where the postlarval stages can survive. In the Barber County area, however, this species has been taken from cave bats (Myotis) and the gray woodrat (Neotoma), both inhabiting rocky canyons with few trees. The deep crevices and damp cool retreats in the canyons probably afford a suitable habitat for this normally forest dwelling chigger.

Life history.--Reared in the laboratory to the adult stage. Duration of prenymphal stage, 8-30 days; duration of nymphal stage, 26-31 days; duration of preadult stage, 9-11 days. Feeding was not observed.

Hosts.--Reptilia: Elaphe obsoleta. Mammalia: Myotis velifer, Sciurus carolinensis, S. niger, Glaucomys volans, Neotoma micropus.

Trombicula gurneyi Ewing

Geographic distribution.--Maryland (Prince George County) south to Florida (Orange County), westward to Texas (Titus County), Oklahoma (Harmon and Cleveland counties), Kansas (Cheyenne County) and Colorado (Yuma County), Statewide in Kansas from Cheyenne to Seward counties in the west, to Doniphan and Bourbon counties in the east.

Ecology.--The larvae of this species have been commonly taken in eastern Kansas on chigger samplers which were laid on rotten logs. It seems to be restricted to that habitat in the eastern part of the range; however, since no similar habitat is present in western Kansas and other western areas, it is thought to inhabit the burrows of small rodents, the common hosts. Evidence to that effect has been obtained in Cleveland County, Oklahoma, where the nest of Neotoma floridana contained an unengorged larvae. The frass of rodent nests may compare favorably with the rotten log frass which supports heavy concentrations in eastern Kansas. Also it appears that few summer species of larval chiggers (ie. Trombicula (Eutrombicula) and Neoschongastia) can survive in the western high plains on the surface of the ground which is shaded and protected only by short to medium-height grasses. The presence of this species on the burrowing owl (Speotyto) supports the burrow and nest theory, and its presence on the red-headed woodpecker (Melanerpes) indicates its occurrence in upright logs and dead trees.

The nymphs and adults have been found in the heart of rotten logs in Titus County, Texas. The lack of eyes, or only faint lenses present, supports the theory of deeper penetration, as opposed to the more external-living species, Trombicula (Eutrombicula) splendens. The species prefers a habitat with a lower temperature, which is indicated by the very early emergence of larvae in the spring (23 April in northeastern Kansas). They are fully active at a temperature nearly 10° F. lower than the common chigger, T. (E.) alfreddugesi. Likewise T. gurneyi requires more moisture both as larvae and in the postlarval stages, than the species (T. alfreddugesi, Neoschongastia americana) which live as active larvae in the open grassland during the summer.

Seasonal occurrence.--February 17 (Oklahoma), April 23 to November in Kansas.

Seasonal abundance.--The larvae appear in large numbers during May in eastern Kansas, and remain common throughout the summer until the dry conditions of the fall reduce and finally eliminate them. Two and possibly three generations in the south, are produced each year.

Life history.--This species was reared from engorged larva to newly-hatched larva. Duration of prenymphal stage, 7-14 days; duration of nymphal stage, 8-18 days; duration of preadult stage, 10-12 days; duration of adult stage prior to oviposition, 24 days; duration of egg stage, 6 days; duration of deutoval stage, 6-10 days; total lapsed time, larva to larva, 61-62 days. Food preferred: Eggs.

Hosts.--Reptilia: Eumeces fasciatus, E. laticeps, E. obsoletus, Sceloporus undulatus, Coluber constrictor, Masticophis flagellum, Elaphe obsoleta, Heterodon nasicus, Heterodon platyrhinos, Pitnophis catenifer, Arizona elegans, Lampropeltis triangulum, Thamnophis sirtalis, Crotalus horridus, and C. viridis. Aves: Melanerpes erythrocephalus, Speotyto cunicularia. Mammalia: Blarina brevicauda, Scalopus aquaticus, Sylvilagus floridanus, Citellus tridecemlinectus, Cynomys ludovicianus, Perognathus hispidus, Dipodomys ordii, Onychomys leucogaster, Peromyscus maniculatus, P. leucopus, Neotoma floridana, N. micropus, Microtus ochrogaster.

Trombicula hoplai Loomis

Geographic distribution.--South central Kansas (Barber County).

Seasonal occurrence.--July and August.

Ecology.--On the basis of the habits of the hosts, this chigger seems to inhabit short-grass prairie and canyon areas. The situations are dry on the surface, but the postlarval stages probably live in burrows, and deep crevices of the rocky canyons.

Life history.--This species was reared to the nymphal stage (duration of prenymphal stage, 13-15 days). No food was taken by the nymphs.

Hosts.--Mammalia: Cynomys ludovicianus, Dipodomys ordii, Peromyscus leucopus and Neotoma micropus.

Trombicula kardosi Loomis

Geographic distribution.--Kansas (Douglas and Allen counties) and southwestern Utah (Garfield County).

Seasonal occurrence.--September (Utah), November and April (Kansas).

Ecology.--Nothing is known of the habitat preference of T. kardosi, except that the Douglas County specimens were taken from squirrels (Sciurus niger) shot from tall Sycamore trees in the valley of a small stream. The forest was not thick, but was extensive.

Life history.--This species was reared to the nymphal stage (duration of prenymphal stage, 6-21 days). Larvae were not completely engorged and did not transform past the nymphal stage, although collembolan eggs were eaten readily.

Hosts.--Reptilia: Elaphe obsoleta. Mammalia: Sciurus niger, Eutamias sp.

Trombicula montanensis Brennan

Geographic distribution.--Great Plains in Alberta, Canada, Montana (Wheatland County), Nebraska (Dundy, Webster counties), Colorado (Boulder, Yuma and Prowers counties), Kansas (Cheyenne and Barber counties east to Wabaunsee County), Oklahoma (Harper County), Texas (Terry County), New Mexico (Santa Fe County) and Utah, (Tooele County).

Seasonal occurrence.--April to October in western and central Kansas.

Ecology.--This species of chigger is very common in the grasslands of the high plains eastward to the central lowlands. The postlarval stages seem to inhabit burrows of grassland mammals and also in nest areas and crevices of canyons where mammals are abundant. Especially common on Cynomys, prairie dogs, it also occurs frequently on other short-grass inhabitants.

Life history.--This species was reared from larva to larva. Duration of prenymphal stage, 10-26 days; duration of nymphal stage, 20 days; duration of preadult stage, 11 days. Neither eggs nor deutovae were observed; larvae appeared after 200 days in culture. Feeding was not observed but eggs were probably taken.

Hosts.--Reptilia: Terrapene ornata, Eumeces obsoletus, Masticophis flagellum, Heterodon nasicus, Heterodon platyrhinos, Rituophis catenifer, Lampropeltis getulus, Crotalus viridis. Aves: Speotyto cunicularia, Cyanocitta cristata, and Muscivora forficata. Mammalia: Sylvilagus nuttalli, Taderida mexicana, Cynomys ludovicianus, Citellus tridecemlineatus, Citellus lateralis, Perognathus flavescens, P. flavus, P. hispidus, Dipodomys ordii, Onychomys leucogaster, Peromyscus maniculatus, Neotoma albigula, N. micropus.

Trombicula trisetica Loomis and Crossley

Geographic distribution.--Eastern Kansas (Douglas and Miami counties).

Seasonal occurrence.--May 26 to November 23.

Ecology.--The larvae have been taken only from woodland vertebrates. This species seems to be uncommon, but probably is found around rotten log and decaying upright trees or large branches, and possibly under the nests of mammals in the woods, either in the logs or under shaded rock ledges. Probably two generations of larvae hatch each year.

Life history.--This species was cultured to the adult stage in the laboratory. Duration of prenymphal stage, 9-11 days; duration of nymphal stage, 18 days; duration of preadult stage, 10 days. Food preferred: Eggs.

Hosts.--Reptilia: Eumeces laticeps, Elaphe obsoleta, Agkistrodon contortrix. Aves: Sialis sialia. Mammalia: Neotoma floridana.

Trombicula twentei Loomis

Geographic distribution.--South central Kansas (Barber County).

Seasonal occurrence.--Taken on hibernating bats in February, 1953.

Ecology.--The only known specimens were taken from the wings and body of several bats, Antrozous bunkeri, in a small cave while hibernating in ceiling crevices. They were fully engorged.

Life history.--This species was not cultured.

Host.--Mammalia: Antrozous bunkeri.

Trombicula species # I

Geographic distribution.--North central Oklahoma (Woods County).

Seasonal occurrence.--August and October 6.

Ecology.--This species has been taken only on Tadarida, the Mexican free-tailed bat, which was present in enormous numbers during the summer in the Merrihew Cave. Presumably this chigger inhabits this cave in the postlarval stages, and the larvae probably appear only during the summer while the bats are present. Other bats (Myotis, Corynorhinus and Eptesicus) collected in the same cave were not infested, but these bats do not inhabit the same rooms in the large cave.

Life history.--This species was reared to the adult stage. Duration of prenymphal stage, 13-14 days; duration of nymphal stage, 32 days; duration of preadult stage, 8-13 days. Food preferred: Eggs.

Hosts.--Mammalia: Tadarida mexicana.

Trombicula species # II

Geographic distribution.--South central Kansas (Barber County) and Colorado (Boulder County).

Seasonal occurrence.--April, July, and August.

Ecology.--This species has been taken from hosts inhabiting canyons dissecting the short-grass prairie, where few trees are present and where little surface moisture exists during the summer. They probably occur in crevices in the rocks, in close proximity to the nests of small rodents.

Life history.--This species was reared from engorged larva to newly-hatched larva. Duration of prenymphal stage, 26 days; duration of nymphal stage 9-21 days; duration of preadult stage, 14 days; duration of adult stage prior to oviposition, 47 days; duration of egg stage, 5 days; duration of deutoval stage, 16 days; total lapsed time, larva to larva, 117-129 days. Food preferred: Eggs.

Hosts.--Mammalia: Peromyscus maniculatus, Peromyscus leucopus, and Neotoma micropus.

Euschongastia criceticola Brennan

Geographic range.--Central Kansas (Barber and Russell counties) westward through the Rocky Mountain States.

Seasonal occurrence.--October to April.

Ecology.--Apparently the larvae and postlarval stages occur in the burrows and nests of rodents in short-grass prairies, canyons and rocky situations.

Life History.--Reared in the laboratory from unengorged larva to newly-hatched larva. Duration of prenymphal stage, 19-22 days; duration of nymphal stage, 6-22 days; duration of preadult stage, 11-17 days; duration of adult stage prior to oviposition, 51 days; duration of egg stage, 51 days; duration of deutoval stage, 16 days; total time, larva to larva, 115-138 days. Food preferred: Eggs.

Hosts.--Mammalia: Cynomys ludovicianus, Peromyscus maniculatus, Peromyscus leucopus, Neotoma floridana, Neotoma micropus.

Euschongastia kardosi Crossley

Geographic range.--Northwestern Kansas (Rawlins County) to southwestern Nebraska (Hitchcock County).

Seasonal occurrence.--July and August.

Ecology.--Apparently short-grass prairie, probably in the burrows and nests of rodents.

Life history.--This species was cultured only to the nymphal stage.

Hosts.--Mammalia: Cynomys ludovicianus, Citellus tridecemlineatus and Perognathus hispidus.

Euschongastia lacerta Brennan

Geographic range.--South central Kansas (Barber County), Colorado (Gunnison County) and California (Santa Cruz County).

Seasonal occurrence.--July to August.

Ecology.--Uncertain; probably found associated with nests of larger rodents, especially in canyons and rocky areas.

Life history.--This species was reared in the laboratory to the adult stage. Duration of prenymphal stage, 21 days; duration of nymphal stage, 31-39 days; duration of preadult stage, 13-15 days. Food preferred: Eggs.

Hosts.--Reptilia: Sceloporus occidentalis. Mammalia: Cynomys ludovicianus, Neotoma micropus, Neotoma albigula, Neotoma mexicana, Neotoma cinerea.

Euschongastia lipovskyi Crossley

Geographic range.--South central Kansas (Barber County) and Texas (Zavala County).

Seasonal occurrence.--July to October.

Ecology.--The larval and postlarval stages are found on hosts living in both short-grass prairies and canyons. They probably occur in close association with burrows and crevices where temperature and humidity are suitable.

Life history.--Engorged larvae were reared to the nymphal stage in the laboratory (duration of prenymphal stage, 28 days). No food was taken by the nymphs.

Hosts.--Mammalia: Sylvilagus floridanus, Cynomys ludovicianus, Perognathus flavus, Perognathus hispidus, Dipodomys ordii, Peromyscus maniculatus, Peromyscus leucopus, Neotoma micropus.

Euschongastia loomisi Lipovsky

Geographic range.--South central Kansas (Barber County), eastern Kansas (Cowley and Douglas counties and southwestern Missouri (Taney County).

Seasonal occurrence.--September to April.

Ecology.--Probably in association with sparse woods and limestone ledges. A series of larvae was obtained from the cave bat (Myotis) in Barber County.

Life history.--Cultured in the laboratory to the nymphal stage (duration of prenymphal stage, 15-20 days). Nymphs fed reluctantly on collembolan eggs.

Hosts.--Mammalia: Cryptotis parva, Myotis velifer, Sylvilagus floridanus, Peromyscus maniculatus, Peromyscus leucopus, and chigger sampler.

Euschongastia peromysci (Ewing)

Geographic range.--Northeastern Oklahoma (Adair and McCurtain counties) and eastern Kansas (Douglas and Jefferson counties) to southeastern Nebraska (Richardson County), eastward through Missouri, Arkansas (Polk and Washington counties); generally distributed throughout southeastern United States.

Seasonal occurrence.--October to May.

Ecology.--Closely associated with woodlands and woodland edge. The larvae are frequently taken from Peromyscus leucopus, trapped in woods. They are possibly another log or stump inhabitant.

Life history.--Reared in the laboratory from engorged larva to newly-hatched larva. Duration of prenymphal stage, 15 days; duration of nymphal stage, 28 days; duration of preadult stage, 10 days; duration of adult stage prior to oviposition, 25 days; duration of egg stage plus deutoval stage, 15 days; total time, larva to larva, 93 days. Food preferred: Eggs. Many cultures of Euschongastia peromysci, also included E.#3 Farrell so that the data from those cultures cannot be used.

Hosts.--Mammalia: Sylvilagus floridanus, Reithrodontomys fulvescens, Reithrodontomys megalotus, Peromyscus maniculatus, Peromyscus leucopus, Peromyscus boylii, Peromyscus gossypinus, Neotoma floridana, Microtus ochrogaster.

Euschongastia pipistrelli Brennan

Geographic range.--Northeastern Oklahoma (Adair County) north to northeastern Kansas (Marshall County), east to Missouri (Stone and McDonald Counties) and Arkansas (Newton County), eastward to Florida and New York.

Seasonal occurrence.--The larvae are probably on the bats throughout the year, actual collections are in September and December.

Ecology.--Apparently restricted to caves.

Life history.--This species was cultured only to the nymphal stage.

Hosts.--Mammalia: Myotis lucifugus, Myotis keenii, Pipistrellus subflavus.

Euschongastia setosa (Ewing)

Geographic range.--North central Oklahoma (Cleveland County) central Kansas (Barber and Russell counties), eastern Kansas (Douglas and Cowley counties), eastward to Georgia and Pennsylvania.

Seasonal occurrence.--Larvae have been taken on hosts in August to April.

Ecology.--These large chiggers are never common, but seem to be associated with woodlands or along rocky or canyon situations. The engorged larvae are found in small cavities usually on the legs or body. These cavities seem to be a result of longer attachment upon the hosts, with the skin of the host growing around it. A frequent host is Peromyscus leucopus.

Life history.--Reared in the laboratory to adult stage. Duration of prenymphal stage, 10-19 days, duration of nymphal stage, 67 days; duration of preadult stage, 10 days. Food preferred: Not observed, but probably eggs.

Hosts.--Mammalia: Sylvilagus floridanus, Sciurus niger, Peromyscus maniculatus, Peromyscus leucopus, Sigmodon hispidus, Neotoma floridana, Neotoma micropus.

Euschongastia sp. #2 Farrell

Geographic range.--Central (Barber and Russell counties) to northeastern Kansas (Douglas County), southward to Oklahoma (Cleveland County) and Arkansas (Polk County).

Seasonal occurrence.--February to November. This seems to be a summer chigger.

Ecology.--The larvae appear frequently on burrowing and fossorial mammals such as the mole (Scalopus) and pocket gopher (Geomys) in addition to the common grassland mammals. It was not collected on hosts in true shortgrass prairie nor in canyon areas.

Life history.--Reared in the laboratory to adult stage. Duration of prenymphal stage, 12-15 days; duration of nymphal stage, 25-26 days; duration of preadult stage, 4 days; duration of adult stage prior to oviposition, 64 days (eggs were eaten by the adults before they developed). Food preferred: Eggs.

Hosts.--Mammalia: Blarina brevicauda, Scalopus aquaticus, Sciurus niger, Cynomys ludovicianus, Geomys bursarius, Perognathus hispidus, Onychomys leucogaster, Peromyscus maniculatus, Sigmodon hispidus, Microtus ochrogaster.

Euschongastia sp. #3 Farrell

Geographic range.--Northeastern Kansas, and southeastern Nebraska (Richardson County) eastward through Iowa to Pennsylvania.

Seasonal occurrence.--October to May.

Ecology.--Found in the tall grass habitat and woodland edge. This species seems to be widespread and common in northeastern Kansas. It is especially common on grassland and meadow mammals. Larvae of this species and E. peromysci are commonly found on the same host animal but the larvae seem to be acquired in separate ecologic niches, and usually one or the other predominate.

Hosts.--Mammalia: Blarina brevicauda, Sylvilagus floridanus, Sciurus niger, Geomys bursarius, Reithrodontomys megalotis, Peromyscus maniculatus, Peromyscus leucopus, Sigmodon hispidus, Neotoma floridana, Microtus (Pitymys) pinetorum, Microtus ochrogaster, Rattus norvegicus, Mus musculus, Canis latrans.

Neoschongastia americana (Hirst)

Geographic range.--Eastern Colorado (Lincoln County) eastward through Texas, Oklahoma, Kansas and Missouri, to Virginia.

Seasonal occurrence.--June to November in Kansas.

Ecology.--This species is a common bird chigger, but it is also a common parasite on cottontails (Sylvilagus) in eastern Kansas. It has not been taken on any other mammal. Unengorged larvae have been taken on chigger samplers in hot, dry open situations, and were swept from tall vegetation. Larvae have been observed to crawl to the top of stumps and move about. Larvae were commonly found on ground nesting birds.

Possible explanations for the absence of N. americana on rodents and other small mammals as their nocturnal habits, avoidance of open areas but host specificity should not be discounted. A parallel situation seems to be the Rabbit Tick, Haemaphysalis leporis-palustris, which is also found on birds. Our only record from Sceloporus is based upon several unengorged larvae, possibly indicating it is an unsuitable host.

Life history.--Reared in the laboratory to adult stage. Duration of prenymphal stage, 15-17 days; duration of nymphal stage, 32-64 days; duration of preadult stage, 11-24 days. Food taken: active forms.

Hosts.--Reptilia: Sceloporus undulatus. Aves: Typanuchus cupido, Colinus virginianus, Rallus elegans. Crotophaga sulcirostris, Speotyto cunicularia, Melanerpes erythrocephalus, Tyrannus tyrannus, Muscivora forficata, Toxostoma rufum, Sialia sialis, Turdus migratorius, Passer domesticus, Molothrus ater, Richmondena cardinalis, Spiza americana, Calamospiza melanocorys, Chondestes grammacus. Mammalia: Sylvilagus floridanus.

Speleocola tadaridae Lipovsky

Geographic distribution.--Northern Oklahoma (Woods County) and south central Kansas (Barber County).

Seasonal occurrence.--Larvae were taken from bats in July, August and September.

Ecology.--This species seems to be host specific to the Mexican Free-tailed bat. Examination of other species of bats in the same and other caves failed to reveal this species, nor were any larvae taken on terrestrial mammals.

Life history.--This species was reared to the nymphal stage (duration of prenymphal stage, 19-20 days). Feeding occurred but was not observed; probably active collembolans were eaten.

Host.--Mammalia: Tadarida mexicana.

Pseudoschongastia hungerfordi Lipovsky

Geographic range.--Eastern Texas (Williamson County) north through Oklahoma to Kansas (Barber and Douglas counties) and Missouri (Lawrence County).

Seasonal occurrence.--Late June to October.

Ecology.--This species, although occurring together with Pseudoschongastia farneri in the western part of its range, seems to require more moisture, has a different larval season and is much more common than farneri in northeastern Kansas. The larvae of this genus are tiny and seem to require shelter and moisture to a greater extent than any other chiggers. They were almost always found deep in the ears of mammals, especially Sylvilagus for P. hungerfordi.

Hosts.--Mammalia: Sylvilagus floridanus, Perognathus flavus, Perognathus hispidus, Dipodomys ordii, Onychomys leucogaster, Reithrodontomys fulvescens, Reithrodontomys megalotis, Peromyscus maniculatus, Peromyscus leucopus, Sigmodon hispidus, Neotoma floridana, Neotoma micropus, Microtus ochrogaster.

Life history.--Reared in the laboratory to adult stage. See table in life history section for details. Food: Active forms.

Pseudoschongastia farneri Lipovsky

Geographic range.--Colorado (Boulder County) eastward through Kansas (Barber, Russell, and Douglas counties) and Oklahoma (Comanche County).

Seasonal occurrence.--Larvae were found from April to October.

Ecology.--The larvae appear earlier than P. hungerfordi, which is distributed over much of the range of farneri. This species seems to inhabit dry grasslands and has not been taken on Sylvilagus floridanus, the most common host for P. hungerfordi.

Life history.--Reared in the laboratory to adult stage. Duration of prenymphal stage, 12-32 days; duration of nymphal stage, 13 days; duration of preadult stage, 13 days. Food preferred: Active forms.

Hosts.--Mammalia: Cryptotis parva, Perognathus hispidus, Dipodomys ordii, Peromyscus maniculatus, Peromyscus leucopus, Sigmodon hispidus, Neotoma floridana, Neotoma micropus, Mus musculus.

Walchia americana Ewing

Geographic range.--Oklahoma (Cleveland and Adair counties) to Kansas (Barber, Douglas, and Miami counties), north to Wisconsin (Dunn County) and east to Florida (Tallahassee).

Seasonal occurrence.--September to March.

Ecology.--Apparently restricted to woodlands (wooded canyons in western Kansas). Common only on Sciurus and Neotoma floridana.

Life history.--Reared in the laboratory from engorged larva to newly-hatched larva. Duration of prenymphal stage, 14-18 days; duration of nymphal stage, 38-41 days; duration of preadult stage, 13-18 days; duration of adult stage prior to oviposition, 226 days; duration of egg stage, 7-9 days; duration of deutoval stage, 6 days; total time, larva to larva, 304-318 days. Food preferred: Active forms.

Hosts.--Mammalia: Sciurus carolinensis, Sciurus niger, Peromyscus leucopus, Neotoma floridana, Neotoma micropus.

Cheladonta sp.

Geographic range.--Arkansas (Polk County) through eastern Kansas (Douglas, Jefferson, and Lyon counties) to Nebraska (Richardson County).

Seasonal occurrence.--November to May.

Ecology.--This species has been taken in grasslands and along the woodland edge.

Life history.--Engorged larvae were reared to the adult stage in the laboratory. Duration of prenymphal stage, 19-21 days; duration of nymphal stage, 81-104 days, duration of preadult stage, 13-14 days. Food preferred: Active forms.

Hosts.--Mammalia: Cryptotis parva, Sylvilagus floridanus, Perognathus hispidus, Peromyscus leucopus, Peromyscus maniculatus, Mus musculus.

Acomatacarus arizonensis Ewing

Geographic distribution.--Southern California (Riverside County), Baja California (Cedros Island), Guerrero, Mexico, Arizona, southeastern Utah (Grand County), southwestern Colorado (Mesa County), northcentral Oklahoma (Woods County) and south central Kansas (Comanche County).

Seasonal occurrence.--A summer chigger, taken in Kansas and Oklahoma in October.

Ecology.--This species seems to be host specific to lizards. All of the known records are from lizards which inhabit a dry environment. The presence of trachea and stigmata seems to be correlated with the dry habitat, since emersion in detergent-water solution and excess moisture were fatal to larvae in the laboratory.

Life history.--One engorged larva transformed to the nymphal stage in culture (length of prenymphal stage, 18 days). No food was taken.

Hosts.--Reptilia: Callisaurus draconoides, Crotaphytus collaris, Dipsosaurus dorsalis, Cnemidophorus labialis, Sceloporus magister, Sceloporus siniferus, Sceloporus jarrovii, Sceloporus undulatus, Uta stansburiana.

See technical report, Greenberg, 1952, for additional information.

Acomatacarus galli Ewing

Geographic distribution.--Southern Texas (Uvalde County), Oklahoma (Cleveland County) and northwestern Kansas (Norton County).

Seasonal occurrence.--26 October in Kansas, November and December in Cleveland County, Oklahoma, January in Texas.

Ecology.--Little is known about this late fall species. It seems to be a grassland inhabitant, but was common on Neotoma floridana, an inhabitant of rock ledges, which usually is found in or near woods.

Life history.--This species was not cultured.

Hosts.--Aves: 'Chicken'. Mammalia: Sylvilagus floridanus, Peromyscus maniculatus, Neotoma floridana.

See both galli and A. angulatus in the technical report, Greenberg, 1952, for additional information.

Acomatacarus polychaetus Greenberg

Geographic distribution.--Northwestern Arkansas (Washington County)

Seasonal occurrence.--March 29-30, 1948.

Ecology.--The few specimens (3) were taken on hosts which inhabited oak woodlands of the Ozark Plateau.

Life history.--This species was not cultured.

Hosts.--Mammalia: Sylvilagus floridanus, Peromyscus leucopus.

See polychaetus and A. whartoni, which are both the same species, in the technical report, Greenberg, 1952, for additional information.

Acomatacarus senase Greenberg

Geographic distribution.--South central Kansas (Barber County).

Seasonal occurrence.--April 11, 1949.

Ecology.--The hosts were taken in a canyon habitat, and the Myotis velifer were taken in a small cave.

Life history.--One engorged larva transformed to the nymphal stage in a laboratory culture (duration of prenymphal stage, 23 days). No food was taken by the nymph.

Hosts.--Mammalia: Myotis velifer, Neotoma micropus.

Acomatacarus (Xenacarus) plumosus Greenberg

Geographic distribution.--Central Kansas (Barber and Russell counties).

Seasonal occurrence.--April, July, August, September and October.

Ecology.--This chigger has been taken from small rodents which live under rocks, in crevices, or in burrows around rocky ledges. The common host is Peromyscus maniculatus.

Life history.--This species was cultured to the nymphal stage in the laboratory (duration of prenymphal stage, 23 days). No food was taken.

Hosts.--Mammalia: Peromyscus maniculatus, Peromyscus leucopus, and Neotoma micropus.

Leeuwenhoekia (Comatacarus) americanus Ewing

Geographic range.--Oregon eastward to Ontario, south to Alabama, northwestern Kansas (Cheyenne County) and Colorado (Archuleta, Boulder and Lesa counties).

Seasonal occurrence.--August (Colorado) and November (Colorado and Kansas).

Ecology.--Larvae were taken in Kansas from hosts in a moist valley meadow habitat surrounded by the short-grass high plains.

Life history.--One engorged larva was cultured to the nymphal stage (duration of prenymphal stage, 9 days). No food was taken by the nymph.

Hosts.--Mammalia: Reithrodontomys megalotis, Peromyscus maniculatus, Neotoma cinerea and Neotoma mexicana.

Hannemania species

Geographic distribution.--Central Nebraska, southward through Kansas into Oklahoma, eastward into Missouri and Arkansas. Statewide in Kansas.

Seasonal occurrence.--Found on frogs over the entire year. The larvae probably appear in the early summer, possibly two generations.

Ecology.--The larvae attack the Amphibia which are terrestrial-aquatic, that is not wholly aquatic (except for breeding), nor are they terrestrial. The larvae and by inference the postlarval stages are to be expected in damp habitats, near areas of permanent water or at least a permanent supply of moisture. The chiggers have been easily cultured in the laboratory under conditions of nearly 100% humidity. Amphibians of northeastern Kansas which have been frequently examined that have not had Hannemania attached are: Ambystoma texanum, Scaphiopus bombifrons, Bufo cognatus, Pseudacris nigrita, Hyla versicolor, Rana areolata, Rana catesbeiana, and Microhyla olivacea.

Life history.--Several cultures were reared from larva to larva. Duration of prenymphal stage, 17-21 days; duration of nymphal stage, 23-30 days; duration of preadult stage, 18-20 days; duration of adult stage prior to oviposition, 16 days; duration of egg stage, 7 days; duration of deutoval stage, 8 days; total time, larva to larva, 89-102 days. Food preferred: Eggs.

Hosts.--Amphibia: Ambystoma tigrinum, Eurycea multiplicata*, Desmognathus fuscus*, Plethodon ouachitae*, Plethodon caddoensis*, Bufo woodhousii, Bufo terrestris, Acris gryllus, Rana pipiens, Microhyla olivacea*.

*possibly representing a second southern species.

HOST-CHIGGER LISTS FOR AMPHIBIA, REPTILIA. AVES AND MAMMALIA COLLECTED IN THE CENTRAL UNITED STATES.

AMPHIBIA

CAUDATA.

Ambystoma tigrinum	Hannemania sp.
Eurycea multiplicata	Hannemania sp.
Desmognathus fuscus	Hannemania sp.
Plethodon caddoensis	Hannemania sp.
Plethodon ouachitae	Hannemania sp.

SALIENTIA.

Bufo terrestris	Hannemania sp.
Bufo woodhousii	Trombicula (E.) alfreddugesi Hannemania sp.
Acris gryllus	Trombicula (E.) alfreddugesi (E.) lipovskyana Hannemania sp.
Rana pipiens	Trombicula (E.) alfreddugesi Hannemania sp.
Microhyla olivacea	Hannemania sp.

REPTILIA

TESTUDINATA.

Terrapene ornata (55)*	Trombicula (E.) alfreddugesi (E.) lipovskyana montanensis

SAURIA.

Holbrookia maculata (13)	Trombicula (E.) alfreddugesi

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* Numbers in parentheses indicate number of individuals examined for chiggers.

Crotaphytus collarus (90)	Trombicula (E.) alfreddugesi (E.) belkini (E.) lipovskyana Acomatacarus arizonensis
Sceloporus jarrovii (11)	Trombicula (E.) belkini Acomatacarus arizonensis
Sceloporus occidentalus (29)	Trombicula (E.) belkini (N.) subsignata Euschongastia lacerta
Sceloporus undulatus (112)	Trombicula (E.) alfreddugesi (E.) belkini gurneyi. Neoschongastia americana Acomatacarus arizonensis
Urosaurus ornatus (2)	Trombicula (E.) alfreddugesi (E.) belkini
Uta stansburiana (1)	Trombicula (E.) alfreddugesi (E.) belkini Acomatacarus arizonensis
Phrynosoma cornutum (50)	Trombicula (E.) alfreddugesi
Eumeces fasciatus (500♦)	Trombicula (E.) alfreddugesi gurneyi
Eumeces laticeps (6)	Trombicula gurneyi trisetica
Eumeces obsoletus (200♣)	Trombicula (E.) alfreddugesi (E.) lipovskyana gurneyi montanensis
Cnemidophorus sackii (6)	Trombicula (E.) alfreddugesi
Cnemidophorus sexlineatus (50)	Trombicula (E.) alfreddugesi
Cnemidophorus tigris (2)	Trombicula (E.) belkini
Ophisaurus attenuatus (16)	Trombicula (E.) alfreddugesi

SERPENTES.

Carphophis amoenus (100♦)	Trombicula (E.) alfreddugesi
Diadophis punctatus (300♦)	Trombicula (E.) alfreddugesi
Heterodon nasicus (12)	Trombicula (E.) alfreddugesi gurneyi montanensis

Heterodon platyrhinos (4)	Trombicula (E.) alfreddugesi gurneyi montanensis
Coluber constrictor (135)	Trombicula (E.) alfreddugesi (E.) lipovskyana gurneyi (E.) sylvilagi
Masticophis flagellum (12)	Trombicula (E.) alfreddugesi gurneyi montanensis
Elaphe guttata (23)	Trombicula (E.) alfreddugesi
Elaphe obsoleta (55)	Trombicula (E.) alfreddugesi (E.) lipovskyana fitchi gurneyi kardosi trisetica
Arizona elegans (2)	Trombicula gurneyi
Pituophis catenifer (27)	Trombicula (E.) alfreddugesi gurneyi montanensis
Lampropeltis calligaster (11)	Trombicula (E.) alfreddugesi
Lampropeltis getulus (4)	Trombicula (E.) alfreddugesi (E.) lipovskyana montanensis
Lampropeltis triangulum (21)	Trombicula (E.) alfreddugesi gurneyi
Sonora episcopa (25)	Trombicula (E.) alfreddugesi
Natrix erythrogaster (4)	Trombicula (E.) alfreddugesi
Natrix rhombifera (1)	Trombicula (E.) alfreddugesi
Natrix sipedon (11)	Trombicula (E.) alfreddugesi
Thamnophis radix (11)	Trombicula (E.) alfreddugesi
Thamnophis sauritus (6)	Trombicula (E.) alfreddugesi
Thamnophis sirtalis (45)	Trombicula (E.) alfreddugesi (E.) lipovskyana (E.) splendens gurneyi

Tropidoclonion lineatum (15)	Trombicula (E.) alfreddugesi
Agkistrodon contortrix (142)	Trombicula (E.) alfreddugesi (E.) lipovskyana (N.) sylvilagi trisetica
Crotalus horridus (27)	Trombicula (E.) alfreddugesi (E.) lipovskyana gurneyi
Crotalus viridis (14)	Trombicula (E.) alfreddugesi gurneyi montanensis

AVES

FALCONIFORMES.	
Buteo jamaicensis (3)	Trombicula (E.) alfreddugesi
GALLIFORMES	
Tympanuchus curido (4)	Trombicula (E.) alfreddugesi (E.) lipovskyana Neoschongastia americana
GRUIFORMES.	
Rallus elegans (1)	Trombicula (E.) alfreddugesi (E.) lipovskyana Neoschongastia americana
CHARADRIIFORMES.	
Capella gallinago (1)	Trombicula (N.) subsignata
Bartramia longicauda (4)	Trombicula (E.) lipovskyana
COLUMBIFORMES.	
Zenaidura macroura (37)	Trombicula (E.) alfreddugesi (E.) lipovskyana
CUCULIFORMES.	
Coccyzus americanus (6)	Trombicula (E.) alfreddugesi
Crotophaga sulcirostris (1)	Trombicula (E.) alfreddugesi Neoschongastia americana
STRIGIFORMES.	
Speotyto cunicularia (5)	Trombicula gurneyi montanensis Neoschongastia americana
Asio otus (1)	Trombicula (N.) sylvilagi

PICIFORMES.

Centurus carolinus (10)	Trombicula (N.) lipovskyi
Melanerpes erythrocephalus (9)	Trombicula (E.) alfreddugesi crossleyi gurneyi Neoschongastia americana

PASSERIFORMES.

Tyrannus tyrannus (9)	Trombicula (E.) lipovskyana Neoschongastia americana
Muscivora forficata (8)	Trombicula montanensis Neoschongastia americana
Empidonax sp. (1)	Trombicula (E.) lipovskyana
Eremophila alpestris (17)	Trombicula (E.) alfreddugesi
Cyanocitta cristata (4)	Trombicula (E.) alfreddugesi montanensis
Corvus brachyrhynchos (4)	Trombicula (N.) lipovskyi Euschongastia peromysci
Parus atricapillus (23)	Trombicula (N.) lipovskyi Euschongastia #3 Farrell
Parus bicolor (8)	Trombicula (E.) alfreddugesi (N.) sylvilagi (N.) whartoni
Parus carolinensis (8)	Trombicula (E.) lipovskyana
Troglodytes aedon (2)	Trombicula (E.) alfreddugesi (E.) lipovskyana
Thryothorus ludovicianus (3)	Trombicula (E.) alfreddugesi
Toxostoma rufum (5)	Trombicula (E.) alfreddugesi (E.) lipovskyana (E.) splendens Neoschongastia americana
Sialia sialis (13)	Trombicula (E.) alfreddugesi (E.) lipovskyana (N.) sylvilagi Neoschongastia americana
Turdus migratorius (17)	Trombicula (E.) alfreddugesi (E.) lipovskyana (N.) sylvilagi Neoschongastia americana

Sturnus vulgaris (11)	Trombicula (E.) alfreddugesi (E.) lipovskyana
Vireo griseus (1)	Neoschongastia americana
Seiurus motacilla (1)	Trombicula (Blankaartia) sp.
Passer domesticus (44)	Trombicula (E.) alfreddugesi (E.) lipovskyana Euschongastia #3 Farrell Neoschongastia americana
Agelaius phoeniceus (37)	Trombicula (E.) alfreddugesi (E.) lipovskyana
Icterus galbula (1)	Trombicula (E.) alfreddugesi
Molothrus ater (39)	Trombicula (E.) alfreddugesi (E.) lipovskyana Neoschongastia americana
Quiscalus quiscula (4)	Trombicula (E.) alfreddugesi (E.) lipovskyana
Sturnella magna (4)	Trombicula (E.) alfreddugesi (E.) lipovskyana
Sturnella neglecta (21)	Trombicula (E.) alfreddugesi (E.) batatas (N.) lipovskyana
Piranga rubra (1)	Trombicula (E.) alfreddugesi
Richmondena cardenalis (35)	Trombicula (E.) alfreddugesi (E.) lipovskyana (N.) lipovskyi (N.) sylvilagi (N.) whartoni Euschongastia # 3 Farrell Neoschongastia americana
Spiza americana (14)	Trombicula (E.) alfreddugesi (E.) lipovskyana Neoschongastia americana
Pipilo erythrophthalmus (1)	Trombicula (E.) alfreddugesi (E.) splendens
Calamospiza melanocorys (9)	Trombicula (E.) alfreddugesi Neoschongastia americana
Chondestes grammacus (9)	Trombicula (E.) alfreddugesi (E.) lipovskyana Neoschongastia americana

Junco hyemalis (29)	Trombicula (N.) sylvilagi (N.) whartoni
Spizella passerina (3)	Trombicula (E.) alfreddugesi
Spizella pusilla (3)	Trombicula (E.) alfreddugesi
Zonotrichia querula (12)	Trombicula (N.) whartoni
Melospiza melodia (17)	Trombicula (N.) lipovskyi

MAMMALIA

MARSUPIALIA

Didelphis marsupialis (11)	Trombicula (E.) alfreddugesi (N.) lipovskyi

INSECTIVORA

Blarina brevicauda (29)	Trombicula (N.) lipovskyi gurneyi Euschongastia #2 Farrell #3 Farrell
Cryptotis parva (16)	Trombicula (E.) alfreddugesi (E.) lipovskyana (N.) sylvilagi Euschongastia loomisi #2 Farrell
Scalopus aquaticus (13)	Trombicula (E.) lipovskyana gurneyi Euschongastia #2 Farrell

CHIROPTERA

Antrozous bunkeri (7)	Trombicula twentei
Myotis lucifugus (20)	Euschongastia pipistrelli
Myotis keenii (15)	Euschongastia pipistrelli
Myotis velifer (620)	Trombicula (E.) alfreddugesi cynos fitchi Euschongastia loomisi Acomatacarus senase
Pipistrellus subflavus (158)	Euschongastia pipistrelli
Tadarida mexicana (500)	Trombicula (E.) alfreddugesi montanensis # I Speleocola tadaridae

LAGOMORPHA

Lepus californicus (10)	*Trombicula* (*N.*) *lipovskyi*
Sylvilagus floridanus (206)	*Trombicula* (*E.*) *alfreddugesi*
	(*E.*) *lipovskyana*
	(*L.*) *myotis*
	(*N.*) *lipovskyi*
	(*N.*) *whartoni*
	(*N.*) *sylvilagi*
	gurneyi
	cynos
	Euschongastia lipovskyi
	peromysci
	loomisi
	setosa
	#3 Farrell
	Neoschongastia americana
	Pseudoschongastia hungerfordi
	Cheladonta sp.
	Acomatacarus galli
	polychaetus

RODENTIA

Sciurus carolinensis (3-)	*Trombicula* (*E.*) *alfreddugesi*
	(*N.*) *lipovskyi*
	(*N.*) *sylvilagi*
	(*N.*) *whartoni*
	cynos
	fitchi
	Walchia americana
Sciurus niger (31)	*Trombicula* (*E.*) *alfreddugesi*
	(*E.*) *lipovskyana*
	(*N.*) *lipovskyi*
	(*N.*) *whartoni*
	cynos
	fitchi
	kardosi
	Euschongastia setosa
	#2 Farrell
	#3 Farrell
	Walchia americana
Cynomys ludovicianus (38)	*Trombicula* (*E.*) *alfreddugesi*
	gurneyi
	hoplae
	montanensis
	Euschongastia cricetícola
	kardosi
	lacerta
	lipovskyi
	setosa
	#2 Farrell

Citellus tridecemlineatus (14)	Trombicula (E.) alfreddugesi gurneyi montanensis Euschongastia kardosi peromysci
Geomys bursarius (5)	Euschongastia #2 Farrell #3 Farrell
Perognathus flavescens (5)	Trombicula (E.) alfreddugesi montanensis
Perognathus flavus (1)	Trombicula montanensis Euschongastia lipovskyi Pseudoschongastia hungerfordi
Perognathus hispidus (37)	Trombicula (E.) alfreddugesi (E.) batatas gurneyi montanensis Euschongastia kardosi lipovskyi #2 Farrell Pseudoschongastia farneri hungerfordi Cheladonta sp.
Dipodomys ordii (48)	Trombicula (E.) alfreddugesi (E.) batatas gurneyi hoblae montanensis Euschongastia lipovskyi Pseudoschongastia farneri hungerfordi
Onychomys leucogaster (15)	Trombicula (E.) alfreddugesi gurneyi montanensis Euschongastia #2 Farrell Pseudoschongastia hungerfordi
Reithrodontomys fulvescens (13)	Trombicula (E.) alfreddugesi (E.) splendens (N.) whartoni Euschongastia peromysci Pseudoschongastia hungerfordi
Reithrodontomys megalotis (107)	Trombicula (E.) alfreddugesi (N.) autumnalis (N.) lipovskyi (N.) loomisi Euschongastia peromysci #3 Farrell Pseudoschongastia hungerfordi Cometacarus americanus

Peromyscus maniculatus (249)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	(N.) loomisi
	(N.) sylvilagi
	(N.) whartoni
	crossleyi
	cynos
	gurneyi
	montenensis
	#II
	Euschongastia cricetícola
	lipovskyi
	loomisi
	peromysci
	setosa
	#2 Farrell
	#3 Farrell
	Pseudoschongastia farneri
	hungerfordi
	Cheladonta sp.
	Comatacarus americanus
	Acomatacarus (X.) plumosus
	Acomatacarus (A.) galli
Peromyscus leucopus (139)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	(N.) richmondi
	(N.) sylvilagi
	(N.) whartoni
	crossleyi
	gurneyi
	hopkae
	#II
	Euschongastia cricetícola
	lipovskyi
	loomisi
	peromysci
	setosa
	#3 Farrell
	Pseudoschongastia farneri
	hungerfordi
	Walchia americana
	Cheladonta sp.
	Acomatacarus (X.) plumosus
	(A.) polychaetus
Peromyscus boylii (3)	Euschongastia peromysci
Peromyscus gossypinus (1)	Euschongastia peromysci
Sigmodon hispidus (160)	Trombicula (E.) alfreddugesi
	(E.) lipovskyana
	(N.) lipovskyi
	(N.) whartoni

	Euschongastia peromysci
	setosa
	#2 Farrell
	#3 Farrell
	Pseudoschongastia farneri
	hungerfordi
	Haldhia americana
	Cheladonta sp.
	Acomatacarus (A.) plumosus
	(A.) polychaetus
Peromyscus boylii (3)	Euschongastia peromysci
Peromyscus gossypinus (1)	Euschongastia peromysci
Sigmodon hispidus (160)	Trombicula (E.) alfreddugesi
	(E.) lipovskyana
	(N.) lipovskyi
	(N.) whartoni
	Euschongastia peromysci
	setosa
	#2 Farrell
	#3 Farrell
	Pseudoschongastia farneri
	hungerfordi
Neotoma floridana (81)	Trombicula (E.) alfreddugesi
	(E.) lipovskyana
	(L.) myotis
	(N.) lipovskyi
	(N.) sylvilagi
	(N.) whartoni
	cynos
	gurneyi
	myotis
	trisetica
	Euschongastia peromysci
	setosa
	#3
	Pseudoschongastia farneri
	hungerfordi
	Haldhia americana
	Acomatacarus gilli
Neotoma micropus (74)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	(L.) myotis
	fitchi
	gurneyi
	hoplae
	montanensis
	#II
	Euschongastia criceticola
	lacerta
	lipovskyi
	locmisi
	setosa

	Pseudoschongastia farneri
	hungerfordi
	Walchia americana
	Acomatacarus (A.) plumosus
	senase
Microtus pinetorum (13)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	(N.) whartoni
	Euschongastia #2 Farrell
	#3 Farrell
Microtus ochrogaster (233)	Trombicula (E.) alfreddugesi
	(E.) lipovskyana
	(E.) splendens
	(N.) autumnalis
	(N.) lipovskyi
	(N.) sylvilagi
	(N.) whartoni
	gurneyi
	Euschongastia peromysci
	#2 Farrell
	#3 Farrell
	Pseudoschongastia hungerfordi
Microtus pennsylvanicus (28)	Trombicula (N.) autumnalis
	(N.) whartoni
Rattus norvegicus (4)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	Euschongastia #3 Farrell
Mus musculus (85)	Trombicula (E.) alfreddugesi
	(N.) lipovskyi
	(N.) loomisi
	(N.) sylvilagi
	(N.) whartoni
	Euschongastia #3 Farrell
	Pseudoschongastia farneri
	Chelodonta sp.
Zapus hudsonius (1)	Trombicula (N.) sylvilagi
CARNIVORA	
Canis latrans (9)	Trombicula (N.) lipovskyi
	Euschongastia #3 Farrell
Canis familiaris (1)	Trombicula (E.) alfreddugesi
	(E.) lipovskyana
Procyon lotor (1)	Trombicula (E.) alfreddugesi
PRIMATES	
Homo sapiens (1)	Trombicula (E.) alfreddugesi

HABITATS OF ACTIVE LARVAL CHIGGERS IN NORTHEASTERN KANSAS.

An attempt has been made to determine the particular habitat of each species of chigger, by collecting of active unengorged larvae in the field, by determination of the habitats of the hosts, and by discovery of the nymphs and adults in the field. The habitat of the postlarval stages is by inference the same approximate situation as that of the active unengorged larvae.

The chigger species which are found predominately in the grassland habitats are: Pseudoschongastia farneri and P. hungerfordi, Trombicula (Eutrombicula) alfreddugesi and lipovskyana, T. (Neotrombicula) lipovskyi, Neoschongastia americana, Euschongastia sp. #2 and E. #3.

Those living predominately in a deciduous woodland habitat are: Walchia americana, Trombicula cynos, T. gurneyi, T. trisetica, T. fitchi, T. (Neotrombicula) whartoni, Euschongastia peromysci and E. setosa.

Several species do not appear to be found predominately in either grassland or woodland, but are probably most common in the grassland-woodland ecotone, usually in association with limestone outcroppings. They are: Trombicula (Neotrombicula) sylvilagi, Cheladonta, and Euschongastia loomisi.

In the grassland habitat (including areas of overgrowth of weeds, or open areas) the following divisions can be made according to chigger preferences. The burrows and underground nests of small mammals are probably particularily important as the habitat of Pseudoschongastia, with P. farneri in the higher, drier grasslands, and P. hungerfordi in the lower moister areas probably including the forest floor. Euschongastia #2 also appears to be closely associated with small mammals which are fossorial in habits (ie. Scalopus, Geomys, Blarina and other burrow dwellers). Euschongastia # 3 and Trombicula (Neotrombicula) lipovskyi are certainly in close association with burrows and runs in grasslands, while the common and widespread T. (Eutrombicula) alfreddugesi is abundant throughout the grass and into some partially wooded situations. The second, less common species T. (E.) lipovskyana, seems to be restricted to moist grass lands, usually in low valleys where the area remains moist throughout the year. This species seems to be restricted to areas which receive large amounts of rainfall (3½" and over). It has not been found in western Kansas. Neoschongastia americana seems to be able to survive better in more open drier situations than most species. It is found both in open grassland areas and in the woodland barren floor. Larvae have also been taken by sweeping in grass and have been known to crawl up stumps and logs. It seems that birds obtain this larvae predominately from the bare ground rather than in trees, although they do occur in and around upright stumps and decayed tree trunks.

The forest species have been difficult to discover in their habitats, and seem to be more restricted, in general, as to hosts upon which they attach. Trombicula gurneyi is most common around fallen decaying logs, especially in the 'frass' areas. Stumps, upright decaying tree trunks, and the frass around logs are all excellent areas for these larvae. The adults and nymphs are found deep within the logs, usually deeper than adult or nymphal Eutrombicula which may live and forage just beneath the loose bark. Positive host data from semi-arboreal and forest vertebrates, points to the fact that Walchia, Trombicula cynos, T. fitchi & T. trisetica are probably intimately associated with mammal nests or other cavities in upright decaying trees, and also mammal nests (such as Neotoma) on the forest floor in all but T. fitchi. It appears that none of these species, however, is common or widespread, and that they require a habitat which provides the proper kind and amount of food, moisture and temperature for the postlarval stages. In this area we have not been able to closely connect these species with any restricted habitat in the woods: Euschongastia peromysci, E. setosa and Trombicula (N.) whartoni, but the latter is certainly restricted to moist situations.

CHIGGER - HOST RELATIONSHIPS

Summary and conclusions.--Approximately 7,000 individuals of 235 vertebrate species have been examined for attached chigger larvae. These vertebrates were principally from Kansas, but were also obtained from Arkansas, Colorado, Missouri, Nebraska, Oklahoma and Texas. Project members examined 1075 individuals of 32 species of amphibians, 2236 individuals of 56 species of reptiles, 657 individuals of 97 species of birds and 3032 individuals of 50 species of mammals. A total of 95 vertebrate species did not have chiggers attached, however most of these were probably sampled too few times or at the wrong season. The latter is especially true of reptiles (25 species negative) and birds (48 species negative). This should not be true of amphibians (22 species negative), since Hannemania is found throughout the year. In the case of mammals (9 species negative) all but one, a bat Corynorhinus, were certainly due to small samples.

On the basis of information gathered, the following can be stated about the chigger-host relationships in our region. Forty species of chiggers have been taken in Kansas, while five additional species have been found in Colorado, Nebraska, Missouri, Oklahoma and Arkansas near the borders of Kansas.

Of these forty-five species, forty-three have been taken on one or more species of mammals. Twenty-four chigger species have been found only on mammals, four of these being found solely upon bats. Mammals are the principal hosts of twelve of the remaining nineteen species. Thus the larvae of only nine of the total of 45 species commonly attach upon other vertebrates.

The best mammalian hosts, in number of chigger species, are those which are abundant, widespread and active in various habitats during the entire year. Examples are Sylvilagus floridanus, Neotoma floridana, N. micropus, Peromyscus maniculatus and P. leucopus. Mammals that are abundant and widespread in a comparatively limited habitat are usually good hosts for one or a few chigger species, such as the grassland mammals Sigmodon hispidus and Microtus ochrogaster.

Birds have been found to be hosts for 16 chigger species, of which 8 species have been commonly found on one or several bird species. Birds seem to be important hosts of Trombicula (E.) lipovskyana, Neoschongastia americana (also common on rabbits) T. crossleyi, and to a lesser extent, relatively speaking, T. (E.) alfreddugesi.

Fourteen chigger species have been found attached to reptiles. However, two species, Trombicula (N.) sylvilagi and Neoschongastia americana have been found only as unengorged larvae, indicating that reptiles are not suitable hosts for them. Reptiles are important hosts for 8 species, including Acomatacarus arizonensis which seems to be restricted to lizards. They seem to be the most important hosts for Trombicula (E.) alfreddugesi, T. (E.) splendens, T. gurneyi and T. trisetica.

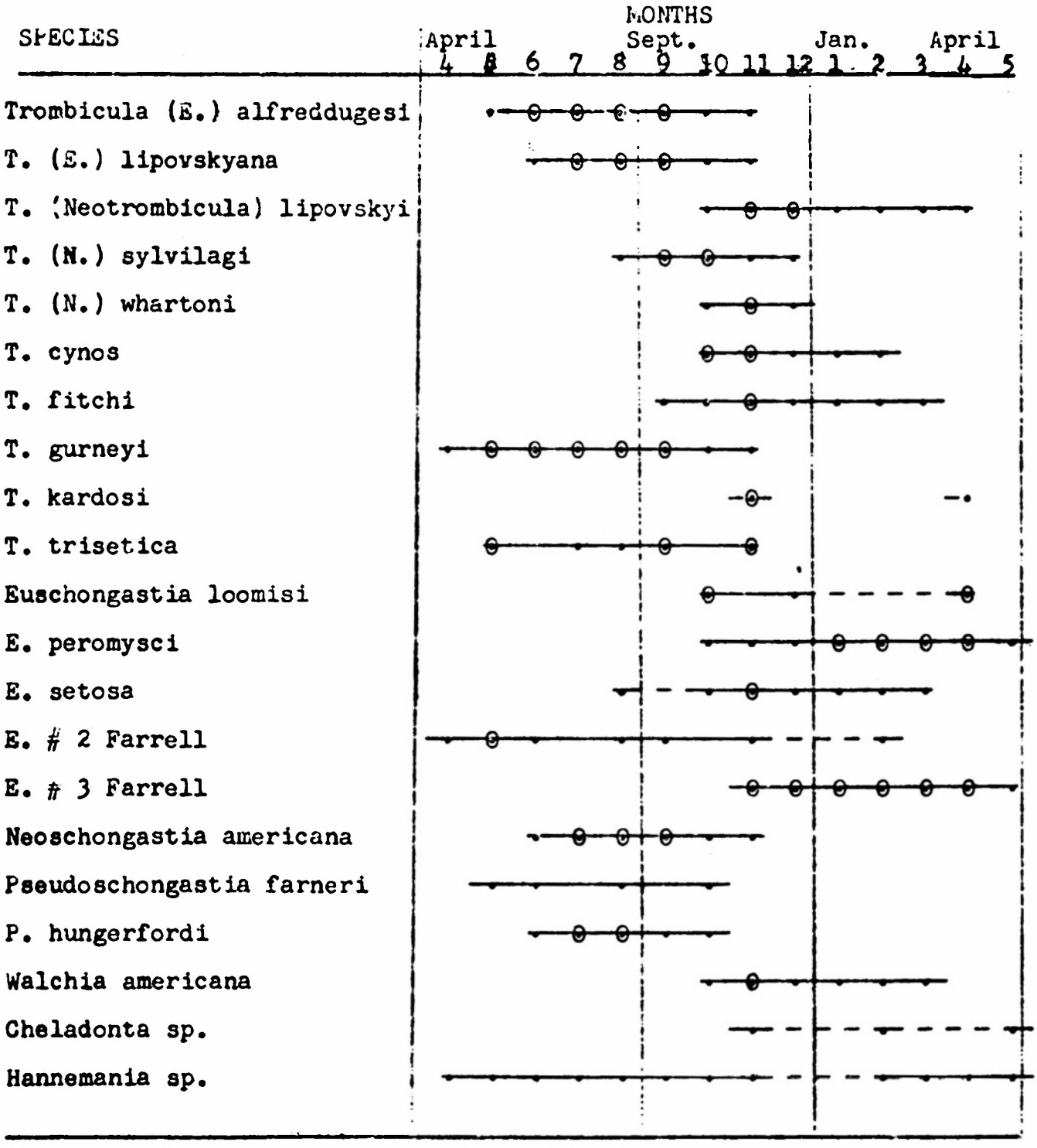
The chigger genus Hannemania parasitizes amphibians only; however larvae of T. (Eutrombicula) occasionally attach to the

skin of toads and frogs.

The unattached larval chiggers are seasonal in emergence, and are usually found in one or a few habitats. Few larvae seem to be host specific, even to vertebrate class, but will crawl onto any available object which stimulates their activity. Their ability to find and crawl upon available vertebrate does not however assure successful attachment and engorgement, since the proper habitat or niche may not be present. Many species need mammalian ears for proper shelter and humidity while most species prefer a sheltered, moist situation for attachment.

Usually only one generation of larvae is produced each year in our region. Exceptions seem to be Trombicula (Eutrombicula) alfreddugesi, T. gurneyi, T. trisetica and possibly others. All of the species with a possibility of two generations are summer, or spring and summer chiggers. The larvae which engorge in the spring or early summer will be able to develop rapidly during the warm summer months, producing larvae late in the summer. The larvae of each species seem to appear at the same approximate time every year. Temperature is important in the rate of egg development, degree of larval activity and probably the length of time unengorged larvae can survive, with relatively lower temperatures slowing them down, but prolonging life. The amount of moisture seems to determine the relative abundance and also the length of total larval activity, especially in the fall. The chigger species can be classified on the basis of the time of larval appearance and abundance. In our region, there seems to be six spring and summer, fifteen summer, five fall and sixteen winter species of chiggers. Of course, there is a great deal of overlap in seasonal occurrence, but usually only one or a few species appear in abundance at the same time in the same ecological habitat. (See the table on larval seasonal occurrence in northeastern Kansas).

LARVAL SEASONAL OCCURRENCE IN NORTHEASTERN KANSAS.



Explanation of the table. The normal larval occurrence is shown by the solid line, while isolated records are connected by a dashed line. Dots indicate actual records and open circles show the period or periods of greater larval abundance. Only one complete cycle is given.

LABORATORY LIFE HISTORY STUDIES

The life histories of chigger mites were first investigated in 1900-1920 by several Japanese workers (Tanaka, 1899; Miyajima and Okamura, 1917) who became interested in the relationship between these mites and scrub typhus. These workers discovered the various postlarval stages and recognized the relationship of chigger mites to Trombicula minor Berlese. Ewing 1926 reared Trombicula (Eutrombicula) alfreddugesi and Hanneminia hylae; Melvin (1946) reared Trombicula batatas and Michener (1946) reared this species as well as T. alleei and T. velascoi. Also Wharton (1946) reared Euschongastia indica by utilizing insect eggs (mosquitoes) and thereby established a suitable laboratory food for the postlarval stages.

Thus at the beginning of this project, the life histories of few species of trombiculids had been thoroughly studied. Concurrently, other workers have also investigated life histories; Jenkins (1949) studied species of Trombicula (Eutrombicula), and Richards (1951) and Jones (1951) investigated Trombicula (Neotrombicula) autumnalis in England. At Duke University, Wharton and his students have also been engaged in life history studies.

A large number of species of chigger mites has been cultured at Kansas for the dual purpose of obtaining postlarval stages for study while accumulating data concerning life histories. While the former objective has been accomplished to a satisfactory extent, the life histories are incompletely known for most species of chiggers studied. Approximately one-third of the species cultured have been carried completely from larva to larva in laboratory cultures; most of the remaining species have been cultured from engorged larvae to the adult stage but have not laid eggs for the next generation.

Developmental Cycle

Engorged larvae which leave the host are active for several days before becoming quiescent. In laboratory cultures where chiggers are forceably removed from the host, this period of activity may extend to more than a week; the degree of engorgement is probably the important factor. After several days of activity, the mites become quiescent and soon enter the prenymphal stage. During this inactive stage most of the larval tissues are resorbed, and the nymphal skin and organs are formed within the larval skin. All of the structures are re-formed; the nymphal legs are not formed inside the larval legs but are developed separately, as are the other appendages. The prenymphal stage can be broken into two stages, namely, a quiescent stage preceding a chrysalis stage in which re-formation takes place. However, these stages cannot be accurately separated in the living mite; rather than use an arbitrary division the prenymphal stage is designated as lasting from the beginning of larval quiescence to the emergence of the nymph. The duration of this stage is one to two weeks and is probably influenced by temperature, humidity, and other external factors as well as the degree of engorgement of the larvae (see Kardos, 1953, on Trombicula (Neotrombicula) lipovskyi).

The nymph emerges from the split larval skin in a soft and delicate condition. The skin hardens sufficiently for rapid movement within an hour, but complete hardening of the more sclerotized structures, e.g. the scutum, may require more than a day. The intensity of nymphal activities varies with the species, as does the type of food preferred (eggs or active organisms.) Duration of the nymphal stage is dependent upon food supply and temperature; the stage lasts at least a week, usually two weeks, and may be extended many months by adverse temperature or limited food.

The nymph becomes quiescent and enters the preadult stage in the same manner as the larva. Tissues are again resorbed and adult appendages are formed independently of nymphal appendages. After one to two weeks (rarely several days) the nymphal skin splits and the adult emerges.

The adult lifetime has not been adequately measured. Individual adults have survived for more than a year and possibly live much longer. There is some evidence that females die after laying eggs. Copulation has not been observed in any species. Dependent on food, temperature, and probably other factors, eggs are laid not less than a week and usually several weeks after adult emergence. Most species probably produce but one generation a year, the unfavorable seasons are probably passed in whatever stage occurs at that time. Inherent mechanisms possibly prevent oviposition for eight to nine months in certain species (Walchia americana). Certain Neotrombicula pass the winter as engorged larvae (see Kardos, 1953) Entrombicula as adults, etc.

Eggs are laid singly or in small groups, in depressions or cracks in the lining of the culture container. After about one week, the eggshell splits but embryological development continues in an enclosing membrane; this is the deutoval stage. The development of the deutovum may be gauged by the increasing intensity of pigmentation. After approximately one week, the larva emerges. Little data was collected on the length of time required for larval engorgement. A minimum of 3 days (T. (E.) alfreddugesi) and a maximum of 30 days or more in others, (particularly Trombicula attached to reptiles.)

This generalized statement of the life history is drawn from laboratory data but is applicable to conditions in nature. Variations in food supply and temperature would lengthen the duration of the active postlarval stages. Temperature affects the length of the inactive stages (Kardos, 1953, on Trombicula lipovskyi).

Life History Data

The table presents life history data on species cultured at Kansas giving the observed duration of the stages in days. Thirty-three species are included; of these, twelve species produced second generation larvae, eleven species were reared to adult but did not produce larvae, and ten species did not reach the adult stage. The majority of the failures in the latter cases were due to poor culture

conditions and these species can probably be more successfully cultured in later attempts.

Techniques for culturing are given in a preceding portion of this report. Engorged larvae which are placed in culture tubes must be carefully examined and determined to be a single species. A contaminant or second species may be easily detected in mounted postlarval specimens but the presence of even one such individual in a culture renders the life history data nearly worthless from that culture, since extremes noted may actually pertain to the contaminant. In the early stages of the project several species were commonly cultured together; therefore, the data included herein are based wherever possible on the more recent "pure" cultures.

Subfamily Trombiculinae

As indicated in the table, the subgenus Trombicula (Eutrombicula) approximates the generalized life history given above. These species are abundant, relatively easy to culture and much information on the common pest chigger T.(E.) alfreddugesi and its relative, T.(E.) splendens, has been gathered. Duration of the egg stage of T(E.) lipovskyana (30 days) is worthy of note (Wolfenbarger , 1953). Other members of the genus Trombicula show variation in the duration of the stages, but this unusually long duration may be due to poor culture conditions. However, the lengthened prenymphal stage of T. montanensis T.#II, and T. lipovskyi is shown in many cultures and probably represents an inherit factor. In contrast, T. trisetica and T. crossleyi show relatively short and constant duration of the inactive postlarval stages. Members of the genus Trombicula prefer eggs as food in culture. (However, T. hoplai did not feed in culture).

Species of the genus Euschongastia are very similar to Trombicula in duration of the stages; some species show a lengthening of the prenymphal stage. The extremely short preadult stage (4 days) of Euschongastia sp. #2 Farrell is worthy of note. Eggs are the preferred food of these species in culture, however, E. loomisi fed reluctantly and E. lipovskyi did not feed.

More than a dozen cultures of Neoschongastia americana failed to produce larvae. Apparently an environmental requirement as yet unknown has not been satisfied. The duration of the life history stages is not unusual. In culture, this species feeds upon the active stages of collembolans.

Subfamily Leeuwenhoekiinae

Many cultures of the genus Hannemania indicate surprisingly little variation in the duration of the various stages; possibly this genus is relatively independent of the effects of such environmental factors as temperature. The high humidity of the culture tubes and dishes approximates the natural condition for these chiggers, as the larvae are found only on amphibians. Cultures were maintained with very little difficulty. Collembola eggs were readily eaten.

Species of Acomatacarus were only recently cultured to the nymphal stage. Earlier cultures presumably failed because these chiggers are adversely affected by the detergent solution normally used in chigger recovery from the host. Environmental factors as yet unknown are blamed for the failure of these cultures to produce adults. Feeding was not observed and may not have occurred.

Subfamily Walchiinae

The genera Walchia, Pseudoschongastia, and Cheladonta have been successfully cultured but only Walchia americana has produced larvae. In view of the relative ease of culturing these species, and the number of cultures which produced adults yet did not produce larvae, it is considered probable that these species produce but one generation a year due to inherit factors; it is thought that if the cultures of Pseudoschongastia had been maintained for a sufficient period of time the life cycle would have been completed. These genera feed exclusively upon the active stages of collembolans.

Conclusions

Although the life histories of many chiggers remain unknown, it is safe to assume that the foregoing data represents a generalized life history of the family. Certainly some species have unusual ecological requirements causing difficulties in culturing (Acomatacarus) and life histories of some unusually adapted species may eventually be found to deviate strongly from this generalized pattern; these species however, can be considered as abervant and not representative of the group on a whole.

Fluctuations in duration of the stages are for the most part too slight to be significant. Either inherit mechanisms or culture conditions could be reponsible.

Indicative but not conclusive evidence is presented that species of the genera Walchia and Pseudoschongastia may be inheritly limited to one generation a year, while the genera Trombicula, Euschongastia and Hannemania are limited mainly by external factors.

Morphological Studies of Postlarval Stages

Of the various stages in the life cycle of trombiculids only the larvae are adequately known. Morphological studies of the other stages are necessary for recognition of those stages when collected in the field and for identification of cultured material not adequately correlated with larvae. Such studies assist also in evaluation of ecological, life history, and related findings. The systematics of the entire group of trombiculid mites would benefit from a careful study of the postlarval stages.

Such studies must, of necessity, be among the last of the investigations attempted, since the material is made available only after collecting methods, culture methods, and correlations are perfected. Consequently morpholcgical studies have not been completed by this project, although they are now being pressed under other auspices at the University of Kansas. It is possible, however, to attempt several generalizations from the data already available from morphological studies.

One outstanding feature of the nymphs and adults is the similarity of the morphological features of the various species, as opposed to the diversity found in larval morphology. Species even in different subfamilies are very similar, and separation of some genera is quite difficult. Womersley (1952) noted such a condition in Australian material and synonomized several genera on this evidence. Womersley's conclusions are not followed by us, since preliminary studies indicate that generic characterizations can be based on morphological features which are slight but nevertheless constant.

An important phase of morphological investigations is the correlation of form with ecological habitat. The free-living nymphs and adults are covered with branched setae; it seems possible to correlate the amount of setation and the degree of branching of the setae with the humidity of the habitat. Many inhabitants of woodlands and similar moist areas posses a greater number of setae with more numerous branches than related kinds of chiggers in grasslands. Some forms inhabiting extremely dry desert areas show strong modifications of these setae, however, so that comparison with other forms is difficult.

LIFE HISTORY DATA FROM LABORATORY CULTURES

(Figures indicate days; all are observed values, except where indicated: *approximation; ** technical report, E. H. Kardos; ? not observed.)

Species	Duration Prenymph Stage	Duration Nymph Stage	Duration Preadult Stage	Duration Adult Stage Prior to Oviposition	Duration Egg Stage	Duration Deutoval Stage	Total time † larva to larva
Trombicula (Eutrombicula) alfreddugesi	6-13	15-120	8-13	7-27	7-9	6-9	49-191
T. (E.) splendens	6-13	15-25	6	8-30	7-9	6-9	48-92
T. (E.) belkini	14	23	7	119	5	11	179
T. (E.) lipovskyana	7*	20*	7*	70	30	8	168*
T. (Neotrombicula) lipovskyi	21-43	15-47	10-18	-	-	-	-
T. (N.) whartoni	22-27	-	-	-	-	-	-
T. (N.) sylvilarvi**	14-17	18	-	-	-	-	-
T. gurneyi	7-14	8-19	10-12	24	6	6-10	61-82
T. montanensis	10-26	20	11	?	?	?	200
T. trisetica	9-11	18	10	-	-	-	-
T. crossleyi	7-8	7-31	10	164	8	11	209-234
T. fitchi	8-30	26-31	9-11	-	-	-	-
T. kardosi	6-21	-	-	-	-	-	-
T. hoplai	13-15	-	-	-	-	-	-
T. (?I)	13-14	32	8-13	-	-	-	-

† From engorged larva to newly-hatched larva. Little data available on time required for larval engorgement; however, a minimum of 3 days to a maximum of 30 days is assumed.

Species	Duration Prenymph Stage	Duration Nymph Stage	Duration Preadult Stage	Duration Adult Stage Prior to Oviposition	Duration Egg Stage	Duration Deutoval Stage	Total time larva to larva
Trombicula (?II)	26	9-21	14	47	5	16	117-129
Euschongastia setosa	10-19	67	10	-	-	-	-
E. paromysci	15	28	10	25	?	?	93
E. lacerta	21	31-39	13-15	-	-	-	-
E. #2 Farrell	12-16	25-26	4	64	-	-	-
E. criceticola	19-22	8-22	11-17	51	10	16	115-138
E. loomisi	15-20	-	-	-	-	-	-
E. lipovskyi	28	-	-	-	-	-	-
Neoschongastia americana	15-17	32-64	11-24	-	-	-	-
Speleocola tadaridae	19-20	-	-	-	-	-	-
Acomatacarus sensae	23	-	-	-	-	-	-
A. arizonensis	18	-	-	-	-	-	-
A. (X.) plumosus	23	-	-	-	-	-	-
Cheladonta sp.	17-21	81-104	13-14	-	-	-	-
Walchia americana	14-18	38-41	13-18	226	7-9	6	304-318
Pseudoschongastia farneri	12-32	13	13	-	-	-	-
P. hungerfordi	11-13	20-23	16-23	-	-	-	-
Leeuwenhoekia (Comatacarus) americanus	9	-	-	-	-	-	-
Hannemania sp.	17-21	23-30	18-20	16	7	8	89-102

INTERNAL MORPHOLOGY AND HISTOLOGY OF ADULT CHIGGERS

Introduction.--This work was undertaken to determine the internal morphology and histology of the nymphal and adult stages of Trombicula (Eutrombicula) splendens, one of the pest chiggers. The following is a preliminary report since the investigations are still in an early stage.

Technique.--In working with the adult stage, it was necessary to develop special techniques of killing, fixing, and embedding. It was found most satisfactory to kill the adults by dropping a piece of ether soaked paper into a vial in which the adults had already been placed. The ether killed them quickly without damage. Immediately after death they were placed in a detergent, to wet the surface so they will sink when placed in the fixative. If not first wetted, they will float on the surface of most fixitives and thus will not be fixed. When using Carnoy's fixative they need not be first wetted; however, Dietrich's has been found to be the fixative giving best results. After washing them in alcohols good results were obtained by dehydrating them in Analin, then placing them in Oil of Bergamot and then in paraffin. Before the paraffin hardens, they should be oriented and the block marked to indicate this orientation. The paraffin embedded specimen should be kept at 0 degrees centigrade for about a week to clear the paraffin, thus making the specimen more readily seen. In specimens fixed in Dietrich's the stains of choice were Delafield's hematoxylin counter-stained with eosin and Mann's acid hematein counter-stained with eosin.

Besides examining sectioned material, it was found helpful to examine dissected material. The adults were placed in Carnoy's for one hour or they were placed in Analin, then into Oil of Bergamot, before dissection. Both methods gave equal results.

Integument.--The integument was found to be much like that of Tetranychus telarius (Blauvelt, 1945). The cells are almost rectangular in section, the cytoplasm stains little and appears gray, while the nuclei are small and dark-staining.

Mouthparts and Glands.--A good deal of sectioned and dissected material was examined and the worker thus far is in agreement with Brown (1952).

Respiratory system.--No indication of a respiratory system has been found in the adult stages.

Central nervous system.--The brain, situated beneath the scutum, appears to be fused to the subesophageal and ganglionic masses. The neuropile is surrounded by a peripheral cellular area which is in turn surrounded by a neurolemma. The narrow esophagus passes back and up through the central part. The exact number and paths of the nerves have not yet been determined, however, a pair of nerves has been noted which pass ventrally and forward, a pair dorsally toward the eyes, a single nerve backward along the eosphagus, a pair forward and dorsally toward the chelicerae, four pairs toward the legs, and a ventral pair backward into the body.

Musculature.--The muscles are of the striated type. There are several dorsal longitudinal and dorsoventral body muscles which contract and expand the abdomen, thus probably aiding in pumping food into the digestive tract, eliminating waste, laying eggs in females, and circulating the blood. Also present are numerous muscles of the leg segments, mouth parts, and genitalia.

Digestive System.--A pharynx opens into a narrow esophagus which passes backward and upward through the brain and into the mid-intestine. The epithelial cells of the esophagus are in a thin layer and have dark staining nuclei. At the point where the esophagus enters the mid-intestine, there is a slight thickening which appears to be a valve acting to keep food from passing back into the esophagus.

The mid-intestine occupies most of the body of the adults. The cells are large and of various shapes. The cytoplasm has numerous vacuoles.

An open connection between the hind-intestine and the mid-intestine has not been found, however, the hind intestine appears to contact the fore part of the mid-intestine, then it passes down through the middle of the mid-intestine, ventrally to the anus. The cell walls of the hind intestine are indistinct and the cytoplasm when stained with Delafield's hematoxylin appears reddish.

Female reproductive system.--The females have a bilobed ovary which lies ventrally. Oogonia occupy the anterior part and mature eggs the posterior part. The exact nature of the oviduct and vagina has not been determined.

Male reproductive system.--The male testis is also bilobed and occupies a ventral position. In the testis can be seen numerous sperm cells. The testis opens into a seminal vesicle which in turn passes into the ejaculatory duct. The penis is a pear shaped organ with muscles attached to its base.

Circulatory system.--The circulatory system appears to be an open system with the blood slushing about without a definite course throughout the body cavity. The blood itself seems to be made up of a fluid or plasma portion and a cellular portion. The cells are large with large nuclei. Also present in the body cavity are cells which look very much like urate cells of insects.

The above report gives a brief resume of the work done up to this time. Investigations are continuing to determine many of the more detailed aspects of the internal anatomy and histology of this and other species of chigger mites.

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