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BIOLOGICAL AND SYSTEMATIC STUDIES ON THE
SUBGENUS NEOTROMBICULA (GENUS TROMBICULA)
IN THE UNITED STATES (ACARINA, TROMBICULIDAE)

by

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INTRODUCTION

This paper comprises taxonomic, ecological, and biological studies on the chiggers of the subgenus Neotrombicula Hirst from the states of Utah, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Missouri, and Arkansas. The taxonomic studies of larvae were based almost entirely on specimens in the University of Kansas Snow Entomological Museum. In the descriptions of new species, the description is based on the holotype with differences occurring in the paratypes indicated in parentheses. Under the heading, additional records, is included information on previously published records from the states concerned. All scutal measurements are included in table 8. The terminology used in this paper follows that proposed by Wharton et al. (1951). The ecological and biological studies were largely confined to those species occurring in northeastern Kansas (particularly Douglas County), although host and habitat data are provided for other areas.

The larval chiggers of the subgenus Neotrombicula were taken only from birds and mammals although many

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reptiles have been examined from areas where Neotrombicula is common. These hosts were obtained by shooting, in the case of birds and larger mammals, and snap or live trapping for smaller mammals. Each specimen or specimens of each species from each locality were assigned a field number which correlates them with all recorded data. The birds and mammals were placed according to field number into separate bags. In the laboratory the bags were placed in the refrigerator and kept there at approximately 40° F. from one to several days. They were then removed, usually examined to determine the location of the chiggers, and warmed at room temperature for one to two hours. Following this they were washed two or three times in a solution of synthetic detergent and water. The solution was then decanted, the residue was examined under a dissecting microscope and the larval chiggers were recovered and sorted. The animals were always examined after washing to find and recover any remaining chiggers, particularly in the ears. This washing method is discussed in detail by Lipovsky (1951b). However, some hosts, particularly those from the Rocky Mountain region, were superficially examined and the chiggers were removed and preserved in the field. Mammals which were live-trapped were placed in screen cages over pans containing a synthetic detergent in water, that caught fully engorged chiggers which dropped from the host. After recording the numbers and kinds

recovered from each host, the chiggers were either preserved in 75 to 85 percent ethyl alcohol or were cultured.

The number of each species of chiggers from each host was determined either immediately after removal from the hosts or after preservation. When only a few chiggers were recovered they were all mounted. However, whenever larger numbers were recovered, the Neotrombicula were separated from the other genera and subgenera by characters seen with the aid of a dissecting microscope at 96 power. The color of the living Neotrombicula was usually red (unengorged) to relatively bright orange (engorged). One specimen of Trombicula whartoni, however, was bright yellow. This character can not be used with preserved specimens as they lose their color. The other characters visible with a dissecting microscope include the relative size and body shape, the flagelliform sensilla, the five scutal setae, the long nude setae on leg III, and the relatively longer and fewer body setae (especially when compared to the Euschoengastia of northeastern Kansas). The number of each species of Neotrombicula was estimated by mounting approximately 20 representatives.

The specimens examined in the University of Kansas Snow Entomological Museum (listed as KU, with the slide number) were mounted in a mixture of polyvinyl alcohol

and lacto-phenol (FVA-LP) as reported by Lipovsky (1953b).

A phase contrast microscope was used for all measurements and other detailed microscopic work. The illustrations were made with the aid of a camera lucida. Whenever possible, scutal measurements were made on unengorged or slightly engorged specimens.

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The majority of the hosts of Neotrombicula larvae were collected and identified by Mr. Robert B. Finley, Jr. and Mr. Richard B. Loomis, while other hosts were taken by Mr. L. J. Lipovsky and other members of the chigger project as well as staff members and graduate students in the Departments of Entomology and Zoology at the University of Kansas. Dr. Cluff Hopler of the University of Oklahoma, Department of Zoological Sciences, generously supplied us with the Utah chiggers, and many of the Oklahoma hosts.

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Subgenus Neotrombicula Hirst

Neotrombicula Hirst, 1925, Nature, vol. 116, p. 609

The subgenus Neotrombicula includes all species of Trombicula having the following larval characters: more or less pentagonal scutum; leg III with one or more mastitarsalae, tibia and telofemur III with long nude (mastitibiala and mastifemorala III) or long plumose setae; a single feathered seta present on each coxa; sternal setae arranged 2-2; palpal claw with three prongs.

Brennan and Wharton (1950:156) separated Neotrombicula into several groups based on the number and arrangement of the long nude setae on leg III; these are the "autumnalis" group, the "microti" group, the "bisignata" group, and the remaining ungrouped species. The characteristics of these groups are given in table I.

Table 1

Characteristics of the Groups of Neotrombicula

	autumnalis group	bisignata group	microti group	ungrouped species		
mastitarsala III	1	3	2	2	2	3
mastitibiala ¹ III	0	1	1	1	2	1
mastifemorala ¹ III	0	0	1 ²	0	0	1

1 In the cases where there is no mastifemorala or mastitibiala III present there are long plumose setae in their places.

2 Basal barbs are occasionally present on the mastifemorala III of californica, goodpasteri, and richmondi.

Keys to the Neotrombicula of the United States ³

3 Species discussed in this paper are marked with an asterisk *

(Modified from Brennan and Wharton, 1950)

Autumnalis Group

Only one species known in the United States. . . . autumnalis*

Bisignata Group

1. Seta on palpal femur.nude eusignata
 Seta on palpal femur branched or feathered 2
2. Seta on palpal genu nude; first dorsal
 posthumeral row usually with six (occasionally
 seven) setae. subsignata *
 Seta on palpal genu branched; first posthumeral
 row usually with eight (occasionally sever.)
 setae bisignata

Microti Group

1. Leg I with three genualae dinehartae
 Leg I with one or two genualae. 2
2. Seta on palpal genu nude, on femur usually nude . . . 3
 Seta on palpal genu and on femur branched or
 feathered 6
3. Sensilla nude; seta on palpal femur nude or
 branched. californica
 Sensilla with at least minute barbs; seta
 on palpal femur nude. 4
4. Sensilla with minute basal barbs; first posthumeral
 row with 10 to 14 setae; dorsal setae more than
 40. browni *
 Sensilla with pronounced barbs along most of
 its length; six to nine (rarely ten or eleven)
 setae in the first posthumeral row. 5

5. Galeal setae nude, occasionally one with a
 single branch harperi *
 Galeal seta with one to several branches. . microti *
6. Galeal seta branched. 7
 Galeal seta nude. 10
7. Sensilla with several pronounced apical
 branches. loomisi *
 Sensilla nude or with barbs, never with only
 pronounced apical branches. 8
8. Scutum distinctly flattened posteriorly; sensilla
 nude or with indistinct basal barbs . . . cavicola
 Scutum usually rounded posteriorly; sensilla
 with distinct barbs present 9
9. Sensilla with short barbs on basal half only;
 ratio of posterolateral seta (PL) to
 anterolateral seta (AL) of scutum,
 .6 to .8. fewetti
 Sensilla with pronounced barbs along most of
 its length; ratio PL to AL .9 finleyi *
10. Leg I with one genuala. richmondi *
 Leg I with two genualae 11
11. Humeral setae total three or more goodpasteri
 Humeral setae total two 12

12. Scutum with few and scattered punctae,
 posterior margin angular; sensilla usually
 with few minute basal barbs whartoni *
- Scutum with numerous and evenly distributed
 punctae, posterior margin broadly rounded;
 sensilla with pronounced barbs along most
 of its length lipovskyi *

Ungrouped Species

1. Seta on palpal femur and on genu nude; leg I
 with three genualae; two mastitibialae III
 present sylvilagi *
- Seta on palpal femur and on genu feathered;
 leg I with one or two genualae; one
 mastitibialae III present. 2
2. Galeal seta branched; leg III with
 mastifemorala varians
- Galeal seta nude; leg III without
 mastifemorala 3
3. Leg I with two genualae; lateral seta on palpal
 tibia nude. waynensis
- Leg I with one genuala; lateral seta on
 palpal tibia feathered 4
4. Dorsal setal formula beginning 4-4. farrelli
- Dorsal setal formula beginning 2-6. carterae

Autumnalis Group

The "autumnalis" group is here limited to those species of Neotrombicula that have only a single long nude seta (mastitarsala) on leg III. The only species of this group known from North America is T. autumnalis, which is here recorded from the Western Hemisphere for the first time.

Trombicula (Neotrombicula) autumnalis (Shaw)

Acarus autumnalis Shaw, 1790, Nat. Misc., vol. 2, p. 42.

Trombicula autumnalis, Kneissl, 1916, Zool. Anz., vol. 46, p. 253; Richards, 1950, Parasitol., vol. 40, pp. 105-117, lectotype [=neotype], Berkshire, England, Fair Mile, Warren Farm, Streatley, Oct. 2, 1946, British Museum (Natural History).

Trombicula (Neotrombicula) autumnale, Hirst, 1925, Nature, vol. 116, p. 609.

Trombicula (Neotrombicula) autumnalis, Hirst, 1926, Ann. Appl. Biol. vol. 13, pp. 140-143; Wharton, 1952, Mem. Ent. Soc. Wash., no. 4, pp. 56-58, (includes a comprehensive synonymy).

Diagnosis.— Based on the American specimens. A member of the "autumnalis" group with the following larval characters: palpal femur with feathered seta, genual and

Ecology.- In Dundy County, Nebraska, R. B. Loomis reports that the hosts were trapped along Rock Creek in isolated wet meadows, which are fed by continuously flowing springs. These meadows are situated in or adjacent to a tall grass marshy habitat, in strong contrast to the dispersed clumps of short grasses and yucca on the very dry sandy soil surrounding the valley. A few willows were situated near the meadows along the creek.

Most of the specimens of T. autumnalis from hosts collected in Dundy County, Nebraska, were found in the ears. Only seven of the 68 specimens were partially or fully engorged. The large number of unengorged and slightly engorged autumnalis indicates that the collection date, November 1, 1952, was early in the season and strongly suggests that this is a fall and winter chigger in this locality.

In Dolores County, Colorado, R. B. Finley reports that the nest of the host, Neotoma, was situated among rocks within open woods. The trees were primarily aspen with scattered western yellow pines (Pinus ponderosa). The principle shrubbery within 100 feet of the nest (the approximate range of Neotoma from the nest, according to Finley) included scrub oak (Quercus gambellii) choke cherry (Prunus virginianus), serviceberry (Amelanchier sp.) and Galium sp. Approximately 100 feet from the nest was a hollow characterized by a moist, dark loam soil; irises were present in the hollow. The whole area was moderately shaded.

ventral tibial seta branched, both dorsal and lateral tibial setae nude; three genualae I; six setae present in each of first and second posthumeral rows.

Geographic range.-- North America: southwestern Colorado (Dolores County); southwestern Nebraska (Dundy County); and southcentral Georgia (Lowndes County). Europe (see Wharton, 1952:56-57)

Seasonal occurrence.-- North America: Colorado, Oct. 18; Nebraska, Nov. 1; Georgia, Dec. 11.

Bisignata Group

This group is represented in North America by only three species, of which only T. subsignata is known from the states included in this paper.

Trombicula (Neotrombicula) subsignata Brennan and Wharton

Table 4

Trombicula (Neotrombicula) subsignata Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, no. 1, pp. 159-161, type: USNM no. 1837, Broome Co., N. Y., Microtus pennsylvanicus, Aug. 10, 1947. Wharton, 1952, Mem. Ent. Soc. Wash., no. 4, p. 60.

Diagnosis.-- A member of the "bisignata" group with the larval characters as follows: palpal femoral seta branched, genual and dorsal tibial setae nude; first posthumeral row usually with six, occasionally with seven setae.

Geographic range.-- This species is known from Montana (Ravalli County) south to Colorado (Boulder County); North Dakota (Morton County); Missouri (Taney County); Pennsylvania (Wayne and Warren counties) to New York (Broome County).

Seasonal occurrence.-- In the Rocky Mountain Region the earliest record of this species is June 12, (Ravalli County, Montana, Brennan and Wharton, 1950:161); the latest record is August 15 (Boulder County, Colorado).

Microti Group

This is the largest group of the subgenus, containing fourteen species in North America. With the exception of three, species of this group have two humeral setae and two genualae I. The three species are T. goodpasteri, which has more than two humeral setae, T. richmondi, with a single genuala I, and T. dinehartae, which, according to Brennan and Wharton (1950:179), has three genualae I. Of the fourteen species, eight are known from the states included in this paper.

Trombicula (Neotrombicula) microti Ewing

Table 4,

Trombicula microti Ewing, 1928, Proc. Ent. Soc. Wash., vol. 30, no. 5, p. 80, type; USNM no. 984, Lincoln Co. Wyo., Gravel Creek, tributary of Pacific Creek, Microtus richardsoni macropus, Aug. 13, 1927, coll. O. J. Murie; 1931, Proc. U. S. Nat. Mus., vol. 80, Art. 8, p. 9; 1937, Proc. Biol. Soc. Wash., vol. 50, p. 171. Radford, 1942, Parasit., vol. 34, p. 57. Wharton, 1946, Proc. Ent. Soc. Wash., vol. 48, p. 176. Michener, 1946, Ann. Ent. Soc. Amer., vol. 39, p. 431. Thor and Willmann, 1947, Das Tierreich, lfg. 71b, p. 268. Philip and Fuller, 1950, Parasit. vol. 40, p. 56.

Diagnosis.- A member of the "microti" group with the larval characters as follows: seta on palpal femur and on genu nude; both galeal setae with one or more branches; first posthumeral row usually with six (occasionally seven) setae, less than 40 dorsal body setae; sensilla with pronounced barbs on the apical two-thirds.

Geographic range.- This species is known from the Pacific coastal states of Washington (King County) south to California (Mono County); in the Rocky Mountain region from Alberta (Edmonton), Canada south to New Mexico (Catron County); in the east from Pennsylvania (Wayne and Monroe counties) north through eastern Canada to Labrador (Goose Bay).

Seasonal occurrence.- In the Rocky Mountain region this species has been taken as early as July 19, (San Juan County, Colorado) and as late as October 25, (Ravalli County, Montana, Brennan and Wharton, 1950:166).

Trombicula (Neotrombicula) harperi Ewing

Table 4,

Trombicula harperi Ewing, 1928, Proc. Ent. Soc. Wash., vol. 30, no. 5, p. 79, type: USNM no. 983, Essex County, N. Y., Heart Lake, Napeozapus insignis. Summer, 1926, coll. F. Harper; 1931, Proc. U. S. Nat. Mus., vol. 80, art. 8, p. 8. Philip and Fuller, 1950, Parasit., vol. 40, p. 56.

Eutrombicula harperi Ewing, 1938, Jour. Wash. Acad. Sci., vol. 28, p. 294. Radford, 1942, Parasit., vol. 34, p. 67. Knight, 1951, Canad. Ent., vol. 83, no. 10, pp. 279-280.

Trombicula (Eutrombicula) harperi, Thor and Willmann, 1947, Das Tierreich, lfg. 71b, p. 285.

Trombicula (Neotrombicula) harperi, Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, pp. 170-172. Wharton, 1952, Mem. Ent. Soc. Wash. no. 4, p. 58.

Diagnosis.— A member of the "microti" group with the larval characters as follows: seta on the palpal femur and on genu nude; galeal setae nude (occasionally one with a single branch); usually eight or nine setae in the first posthumeral row, less than 40 dorsal body setae; sensilla with pronounced barbs along most of its length.

Geographic range.— This species is known from British Columbia, (Vancouver, Knight, 1951); the Rocky Mountain region from Montana (Missoula County) and Idaho (Lemhi County) to Wyoming (Washakie County) and Colorado (La

Flata and Conejos counties); and in the east from Pennsylvania (Beaver and Monroe counties) to Maine (Piscataquis County).

Seasonal occurrence.- In the Rocky Mountain region this species has been taken as early as June 11 and as late as August 20 (both records from Ravalli County, Montana, Brennan and Wharton, 1950:171).

Trombicula (Neotrombicula) browni Brennan and Wharton

Trombicula (Neotrombicula) browni Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, no. 1, pp. 178-179, type: USNM, no. 1840, Washakie Co., Wyo., 9 mi. E, 4 mi. N Ten Sleep, at 7000 ft., Peromyscus maniculatus, July 13, 1947. Wharton, 1952, Mem. Wash. Ent. Soc. no. 4, p. 57.

Diagnosis.-- A member of the "microti" group with the larval characters as follows: seta on palpal femur and on genu nude; galeal setae usually single branched; first posthumeral row with ten to fourteen setae, more than 40 dorsal body setae; sensilla with few minute barbs.

Geographic range.-- Known only from the type locality in the Big Horn Mountains of northern Wyoming.

Seasonal occurrence.-- The only collection of this species was made in mid-July.

Table 4

Neotrombicula examined from Wyoming, northeastern Utah, and Colorado

Locality and Date	Total	ques- tion	microti	harperi	browni	subsig- nata	finleyi	autumn- alis
Washakie Co. Wyo. July 13-18, 1947	79			69	10			
Carbon Co. Wyo. July 23-25, 1947	117	1	12	103		1		
Summit Co. Utah Aug. 2, 1951	69		69					
Rio Blanco, Colo. July 27-29, 1947	87	3	6	78				
Boulder Co. Colo. July 31-Aug 8, 1947	156	2		148		6		
Douglas Co. Colo. Aug. 4, 1948	6			6				
Gunnison Co. Colo. Aug. 10, 1948	12		5	7				
Dolores Co. Colo. Oct. 18, 1949	5	1					2	2
San Juan Co. Colo. July 19, 1949	56		1	55				
Saguache Co. Colo. July 31, 1948	11			11				
La Plata Co. Colo. July 4, 1949	1			1				

4 Questionable specimens are probably either T. microti or T. harperi.

Trombicula (Neotrombicula) loomisi new species

Diagnosis.--A member of the "microti" group with the following larval characters: all setae of the first four palpal segments feathered; galeal seta branched; several pronounced apical branches on the sensilla.

Geographic range.--This species is known from the type locality, 1 mile east Laird, Yuma County, in extreme eastern Colorado and from southwestern Nebraska (Dundy County).

Seasonal occurrence.--The type series was obtained from hosts trapped on November 1 and 2, 1952.

Ecology.- The specimen of T. loomisi from Dundy County, Nebraska, was taken from a Peromyscus maniculatus, at the base of a woodrat nest, in the same general area as the hosts of T. autumnalis and T. whartoni. However, loomisi was in a dry situation while the latter two were found in a marshy habitat. The loomisi from Yuma County Colorado, were taken from hosts trapped in a meadow at the edge of the North Fork of the Republican River which had flowing water present despite the drouth throughout the Great Plains at that time. The soil here was predominantly sandy with a good stand of grass.

The larvae, all engorged or only slightly engorged, were recovered by washing the mammals in water and detergent. Preliminary examinations revealed only a single unattached larva crawling on the outer hairs of one ear. The rarity (only five larvae from 14 hosts examined from the Colorado locality) and the relatively unengorged condition indicates that these larvae had just appeared (November 1-2) and strongly suggests that this is a late fall and winter chigger.

Trombicula (Neotrombicula) finleyi new species

Diagnosis.--A member of the "microti" group with the following larval characters: palpal femur and genu each with branched seta; galeal seta branched; sensilla with pronounced barbs along most of its length; ratio of the PL to the AL is .9.

Geographic range.--This species is known only from the type locality; 10 miles east, 15 miles north of Dolores, Dolores County, Colorado.

Seasonal occurrence.--The only collection was made on October 18, 1949.

Ecology.--T. finleyi was collected from the same individual host as T. autumnalis (see the latter for an account of the habitat).

Trombicula (Neotrombicula) richmondi Brennan and Wharton

Trombicula (Neotrombicula) richmondi Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, no. 1, p. 183, type: Somerset Co., Microtus pennsylvanicus, Oct. 16, 1947, Carnegie Museum of Pittsburgh. Wharton, 1952, Mem. Ent. Soc. Wash., no. 4, p. 59.

Diagnosis.- A member of the "microti" group with the larval characters as follows: first four palpal segments with all setae feathered; leg I with a single genuala.

Geographic range.- This species is known from Arkansas (Polk County) and western Pennsylvania (Brennan and Wharton, 1950:183).

Seasonal occurrence.- In Pennsylvania this species has been taken as early as September 27, and as late as April 8 according to Brennan and Wharton (1950:183): in Arkansas the only record was March 29.

Remarks.- The specimen examined from Arkansas has approximately 60 dorsal and 52 ventral setae while one examined from Pennsylvania has approximately 28 dorsal and 40 ventral setae. There were no other significant differences between the two specimens examined.

Trombicula (Neotrombicula) lipovskyi Brennan and Wharton

Figure 1,

Table 5.

Trombicula (Neotrombicula) lipovskyi Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, no. 1, p. 177, type: USNM no. 1838, Norton Co., Kans., 4 mi. W, 1 mi. S Logan, Peromyscus maniculatus, Oct. 25, 1946. Wharton, 1952, Mem. Ent. Soc. Wash., no. 4, p. 59.

Diagnosis.- A member of the "microti" group with the larval characters as follows: all setae on first four palpal segments branched or feathered; galeal seta nude; sensilla with pronounced barbs; scutum broadly rounded posteriorly and with numerous minute punctae.

Geographic range.- This species is known from Kansas (Norton County) and southeast Nebraska (Richardson County) east to Missouri (Pike and Stoddard counties), southward to Arkansas (Folk County) and Oklahoma (McClain County).

Seasonal occurrence.- This species has been taken as early as October 7 (Leavenworth County, Kansas), and as late as April 27 (Douglas and Russell counties, Kansas).

Habitat.- T. lipovskyi is the most abundant Neotrombicula throughout Kansas. In northeastern Kansas, particularly Douglas County, where intensive studies have been conducted, this species is known to occur in grassland as well as woodland habitats; as shown by the host data and by chigger sampling. The six individuals collected on chigger samplers were from the wooded sylvilagi area near the quarry, at the University of Kansas Natural History Reservation (see discussion under T. sylvilagi). In other parts of Kansas where collections have been made, the areas were essentially grassland with few or no trees present.

In Arkansas (Washington and Folk counties) T. lipovskyi was found on Sylvilagus floridanus taken in forest habitats.

Hosts.- In northeastern Kansas, the most important host of T. lipovskyi seems to be Sylvilagus floridanus while other important hosts include Neotoma floridana, Sigmodon hispidus, Microtus ochrogaster, and Sciurus niger in the order of probable importance as hosts. Birds are only minor hosts for this chigger.

The main focus of attachment of lipovskyi on most of the host species examined appears to be within the ears; however considerable numbers may be found on other parts of the body.

One Sciurus niger collected in Douglas County,

Kansas had 30 of 50 lipovskyi attached just below the ears while none were found within the ears; the other 20 chiggers were from other parts of the body.

Several Sylvilagus floridanus collected in Douglas County, Kansas were brought into the laboratory, skinned and divided up into the following divisions: ears, head, feet, the anal and tail region, and the remaining parts of the body. These five portions were washed separately. Two rabbits collected in late November yielded the following combined total of lipovskyi: ears, 129; head, 55; feet, 110; anal and tail region, 31; and body, 41. A single rabbit collected in March gave the following results: ears, 1; head, 1; feet, 3; anal and tail region, 1 larva; with nothing on the body. The examination of rabbits during November revealed small pockets of chiggers attached between the toes. From the above information it can be stated that on Sylvilagus, the major concentrations of lipovskyi are within the ears and on the feet.

Several Neotoma floridana nests as well as one unidentified rodent nest (probably Peromyscus) were collected in Douglas County, Kansas, in November and December during the height of the T. lipovskyi season. They were placed individually into modified Berlese funnels and the residue from the Neotoma nests yielded three unengorged and four fully engorged lipovskyi

larvae, while the unidentified rodent nest yielded one unengorged and three fully engorged lipovskyi larvae. Material obtained in the same way from a Neotoma floridana nest taken in McClain County, Oklahoma during January, 1952, yielded two fully engorged larvae. This indicates that at least some of the fully engorged lipovskyi larvae off the hosts in the nests and that unengorged larvae are also present in the nests.

Seasonal abundance.- Northeastern Kansas and central Oklahoma: In northeastern Kansas the earliest larval record of T. lipovskyi is from Sylvilagus floridanus taken on Oct. 7, 1946, according to Brennan and Wharton, (1950:177). The earliest record during the period studied, from 1947 to 1952, is October 15, 1948, from Sigmodon hispidus. The number of larvae upon the hosts during this period (fig. 1) increased rapidly from the few in October to a peak lasting from the second week in November to mid-December, followed by a sharp decline late in December, lasting through January and February, probably due to the cold weather. In late February and early March, there seems to have been a second, but much smaller increase in larval occurrence on hosts, probably due to the warmer weather. Following this was the decline and disappearance of all larvae by the last of April (last record, April 27, 1952, from Sylvilagus floridanus).

The seasonal abundance of T. lipovskyi on hosts from McClain and Cleveland counties, Oklahoma (Fall, 1951

to Spring, 1952), appeared similar to that found in northeastern Kansas.

Figure 1 presents a summary of the seasonal abundance, from 1947 to 1952, of T. lipovskyi in northeastern Kansas from the four most important hosts, Sylvilagus floridanus, Neotoma floridana, Sigmodon hispidus, and Microtus ochrogaster, based on one-half month periods.

Post-larval development.- The required period for the development of T. lipovskyi in culture tubes from the engorged larva to the adult was approximately 75 days under laboratory conditions and approximately 300 days outdoors (which included over wintering) as shown in table 5. The culture tubes were 5 dram plastic-stoppered opitclear vials lined with a mixture of hardened plaster - of-Paris and charcoal as described by Lipovsky, (1953), which were kept at the proper humidity by adding water. The nymphs were fed the eggs of Sinella curviseta Brook (Entomobryidae, Collembola) as recommended by Lipovsky, (1951a). Several of these culture tubes containing approximately 40 fully engorged larvae were kept at room temperature (75° - 85° F.) in the laboratory; one culture tube was placed in the refrigerator (39° - 42° F.); and one tube was placed outdoors in the soil (November 27, 1951 to July 29, 1952).

The culture tubes in the laboratory were examined every two or three days, with less frequent examinations of the outdoor and refrigerator tubes.

The outdoor culture tube was placed in a vertical position, two to three inches below the soil surface, which was devoid of vegetation, adjacent to the southwest corner of a building. The soil temperature was recorded as low as 28° F. in December and as high as 92° F. in July.

The duration of the larval stage indicated in

table 6 includes the period from the placement of the engorged larvae in the culture tube until they ceased to move their legs. The prenymphal stage (nymphochrysalis or protonymph of some authors), which follows the larval stage, is here divided into two parts: the first being the part of the prenymphal stage which lasts from the time the larval chiggers cease to move until the cuticle starts to split; and secondly, the rest of the prenymphal stage. In order to determine when the larvae have ceased to move and have passed into the first part of the prenymphal stage (not merely inactivity because of the colder temperatures), the outdoor and refrigerator culture tubes were placed in the warm laboratory (temperature 70° - 85°F.) for approximately 15 minutes. When first removed from the colder temperatures, usually all of the chiggers were inactive; however, upon warming at the laboratory temperatures, those still in the larval stage became active. When removed from the refrigerator, the larvae were always inactive.

Individuals of T. lipovskyi remained as larvae for a considerably longer period at the colder temperatures (62 days outdoors, 72 days in refrigerator) than in the laboratory (6 days).

Those chiggers kept in the refrigerator did not enter the second part of the prenymphal stage until they were removed from the cold temperature (approximately eight to nine months after they entered the first part

of the prenymphal stage). However, once transferred to the warmer laboratory, it took only six days for the majority of these chiggers to begin the second part of the prenymphal development; this compares to 19 days for those kept constantly in the laboratory; the difference suggests that some development occurred during the eight to nine months period at 39° - 42° F.

The second part of the prenymphal stage did not appear in the outdoor culture tube until the relatively warmer month of March (following the colder months of January and February). The adult stages first appeared during the last half of June, eight months after the engorged larvae were placed in the culture tube. It appears, therefore, that the larval and the first part of the prenymphal stages overwinter. Furthermore, there seems to be only a single generation of lipovskyi per year.

Table 5
Post-larval Development of T. lipovskyi

Cultures		Lab. 70-85°F.	Refrigerator		Culture tube in soil (outdoors) (Nov. 27 to July 29, 1952)	
			39-42°F.	Lab.	No. Days	Months
Larva	range ⁵ mode ⁶ number ⁷	2-9 ⁵ 6 ⁶ (23) ⁷	28-81 76 (8)		10-82 62 (20)	Nov. 27 to last half of Feb. (overwinter)
Pre- nymph first part	range mode number	11-21 19 (21)	230-283	6-8 6 (7)	129-165 132 (19)	Nov. 29 to first half of April (overwinter)
Pre- nymph second part	range mode number	10-22 13 (20)		10 (5)	32-40 36 (14)	Last half of March to last half of April
Nymph	range mode number	15-30 (9)		44 (1)	49-81 51 (3)	Last half of April to first half of July
Pre- adult	range mode number	15-18 (4)		17 (1)	12-18 13 (3)	Last half of June to last half of July
Adult	number pres.	(4)		(1)	(3)	Appeared the last half of June until last of July

5 The range in days that individuals remain in each stage.

6 The number of days before 51% of the individuals transform to the next stage.

7 The number of individuals surviving each stage and passing into the next stage.

Trombicula (Neotrombicula) whartoni Ewing

Diagnosis.- A member of the "microti" group with the larval characters as follows: all setae on first four palpal segments branched or feathered; galeal seta nude; sensilla with minute to pronounced basal barbs, rarely nude; scutum angular posterior and with few large punctae (Arkansas specimens with the punctae somewhat smaller and more numerous).

Geographic range.- This species is known from western Nebraska (Dundy Co.), Kansas (Nemaha to Miami cos.), Illinois (Champaign Co.), and Pennsylvania (Dauphin Co.), south to Florida (Orange Co.), Mississippi (Harrison to Franklin cos.), and northeastward to Arkansas (Miller to Polk cos.).

Seasonal occurrence.- In Kansas, Nebraska, and Missouri, this species has been taken as early as October 12 (Miami County, Kansas) and as late as January 28 (Pemiscot County, Missouri). In Arkansas (Polk County), this species has been collected March 3 to 29.

Habitat.-- In northeastern Kansas, particularly Douglas County, where intensive collecting has been conducted, this species has been found on hosts in deciduous oak-hickory woodland and woodland edge habitats.

The specimens from Polk and Miller counties, Arkansas were taken from hosts in meadow habitats in oak-pine forest areas according to the collectors, Richard B. Loomis and Leonard M. Koger.

The whartoni from the Dundy County, Nebraska were taken with autumnalis (see habitat notes under the latter). While few trees (small willows), were present, the meadow habitat was marshy.

The specimens from Orange County, North Carolina were taken from Duke Forest.

It appears that adequate and relatively consistent soil moisture as well as warm climate conditions are vital factors for the presence of whartoni. This species probably cannot withstand the generally drier and colder conditions of the grasslands of the Great Plains and is, therefore, limited to the relatively moist woodlands to the east and when present in the Great Plains it is restricted to woodlands and marshy habitats.

Hosts.-- The most important hosts of T. whartoni in northeastern Kansas apparently are Sciurus niger and Sylvilagus floridanus (see table 7). Birds are also of some importance as hosts in this area.

Table 6

Trombicula (Neotrombicula) whartoni
collected in northeastern Kansas

Host	No. examined ⁸	No. with <u>whartoni</u>	Total no. <u>whartoni</u>
<u>Sciurus niger</u>	12	6 or 7	42
<u>Sciurus carolinensis</u>	1	1	6
<u>Sylvilagus floridanus</u>	56	3	69
<u>Parus bicolor</u>	2	2	5
<u>Richmondia cardinalis</u>	9	3 or 4	5
<u>Junco hyemalis</u>	12	3	4
<u>Zonotrichia querula</u>	6	1	1
<u>Mus musculus</u>	30	2	3

8 .- Includes only those hosts examined during the
known whartoni season. (mid-October to mid-December)
in this area.

Ungrouped Species

Five species with various combinations of the long whip-like setae on the segment of leg III have not been placed into any named groups. Only one of these, T. sylvilagi, has been collected from the states included in this paper.

Trombicula (Neotrombicula) sylvilagi Brennan and Wharton

Figure 2.

Trombicula (Neotrombicula) sylvilagi Brennan and Wharton, 1950, Amer. Midl. Nat., vol. 44, 1950, no. 1, pp. 186-187, type: Rocky Mountain Laboratory no. 23242, Leavenworth Co., Kans., Sylvilagus floridanus, Oct. 7, 1946. Wharton, 1952, Mem. Ent. Soc. Wash., no. 4, p. 60.

Diagnosis.— An ungrouped species with the larval characters as follows: two mastitibialae III and two mastitarsalae III; three genualae I; palpal femur and genu each with one nude seta; galeal seta nude.

Geographic range.— This species is known from northeastern Kansas (Jefferson, Leavenworth, Douglas, and Miami counties) and central Illinois (Piatt County).

Seasonal occurrence.— Larvae have been taken on chigger samplers as early as August 16 and as late as December 11 in Douglas County, Kansas. The earliest host record is October 5 (Douglas County, Kansas), while the latest is November 21 (Jefferson County, Kansas).

Habitat.- Several plots on the University of Kansas Natural History Reservation have been sampled for active unengorged chigger larvae. Two of these plots, one adjacent to the quarry, called, the sylvilagi and big elm stations, and another in Skink Woods, along Upper Skink Ledge, call rat log area, were found to have Neotrombicula. A description of the Natural History Reservation with a map indicating the location of Skink Woods and the Quarry is given by Fitch (1952).

The sylvilagi and big elm stations, comprising a total area of approximately 50 square feet, are situated on a southeast facing slope. Directly adjacent to the west of this area is the open Quarry, which becomes hot, tending, therefore, to raise the temperatures of these stations. The principal trees in the vicinity are elms, dogwood, and hickory.

The rat log area, approximately 30 square feet in size, is situated on a west facing slope and tends to be cooler and more humid than the Quarry area. Extending over the southern part is an overhanging log (rat log) with grass and debris present beneath it. Above the ledge are gooseberry shrubs, walnut, and hackberry trees; below and along the ledge are American elms and Rhus aromatica.

Both of these areas are situated on the partially shaded forest floor just below limestone ledges. The well-drained soil of the forest floor covers a limestone

derived substrate. The ground cover includes forest litter with a leaf cover present during the fall and winter. The ground in both areas inclines downward from the ledge into the woods. Above the ledge the terrain is level and the trees, which extend but a short distance, are replaced by open grassland. Situated in crevices of the limestone ledges above each of the two areas where Neotrombicula were found were Neotoma nests.

During the periods of the greatest abundance of T. sylvilagi, collections were made in additional areas. These included such habitats as deep within a large cavity at the base of a chestnut-oak tree, on and around a decomposing log deep in the woods, and in grass covered areas adjacent to the woods.

Seasonal abundance.- The number of active larval chiggers present was determined by placing several black, rectangular "Plexiglass" chigger samplers ($5\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ inches) ⁹ on the areas to be sampled. They were placed

9 This procedure was initiated in 1949 by R. B. Loomis and subsequently followed by him as well as the author (1951 and 1952).

firmly on the ground for one or two minutes at the warmer temperatures and five or more minutes in the colder weather. Some samplers were placed on the leaf litter during the height of the larval season for comparison with only a slight difference noted in the abundance of active chiggers. Samples were taken throughout the year;

from late spring through fall samples were usually made every one or two weeks, less frequently the rest of the year. The results of the sampling of T. sylvilagi are summarized in figure 2. During 1952, both the sylvilagi-big elm stations and the rat log area were sampled, while in 1951 only the former was sampled.

The earliest record of a larval T. sylvilagi taken from the soil surface is Aug. 16, 1951. The larval population reached the greatest abundance from early September to mid-October, and rapidly declined until it apparently disappeared by mid-December (latest, December 11, 1952).

The year 1951 was the wettest year recorded in eastern Kansas since 1887, the rainfall being 15 inches above the normal in Lawrence, and the mammal population during the summer and fall was high. Contrary to 1951, the same period (summer and fall) of 1952 was one of the driest on record, with the mammal population dropping extremely low.

During the wet year of 1951, the larval sylvilagi were abundant. The few samples made in the sylvilagi station during the months of September and October in 1949 and 1950 indicate that this species was also abundant then, however the larvae apparently decreased in number more rapidly in these two years than in 1951. The 1952 sylvilagi population was considerably below that of 1949 to 1951, probably due to the extremely dry summer and fall.

A single emaciated sylvilagi (KU 4794) which was collected on December 11, 1952 (see fig. 2) on a sampler placed in a dead grass (Bromus japonicus) habitat located immediately above the quarry and adjacent to woodland. This individual appears to have been a straggler and in the larval stage for some time.

The number of chiggers per square foot indicated in figure 2 was obtained as follows: the number of chiggers taken from an area each week was divided by the number of samplers placed on the ground in that area and multiplied by ten (ten chigger samplers cover approximately one square foot). This is not to imply that the entire area has this population, but only the favorable habitats for sylvilagi.

Post-larval development.- Twenty-two unengorged T. sylvilagi (field no. RL 521008-10, collected in the field on chigger samplers) were placed on a juvenile Mus musculus which was then placed over water containing a synthetic detergent. At the end of three days ten engorged chiggers had been recovered from the water. These ten chiggers were placed together in a Syracuse watch glass with water and detergent and kept in the refrigerator for approximately 2 days; following this they were placed in a culture tube at room temperature. In approximately eleven days (range seven to thirteen) the six surviving larvae entered the prenympchal stage which was completed in approximately 15 days (range 14

to 17 days) by four individuals. Three of the nymphs were preserved while the fourth remained active for 18 days before becoming inactive and apparently entering the preadult stage. This last individual was preserved after three days of inactivity.

Classified list of hosts of Neotrombicula

from the Central United States^{13 14}

13 Includes the following states: Utah, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Missouri, and Arkansas.

14 Items marked by an asterisk (*) are from Brennan and Wharton (1950).

Aves

Galliformes

Colinus virginianus- - - - -T. sylvilagi
(bob-white quail)

Charadriiformes

Capella gallinago delicata- - - - -T. subsignata
(Wilson's snipe)

Strigiformes

Asio otus- - - - -T. lipovskyi
(long-eared owl)

Piciformes

Centurus carolinus- - - - -T. lipovskyi
(red-bellied woodpecker)

Passeriformes

Cyanocitta cristata- - - - -T. whartoni*
(blue jay)

Parus atricapillus- - - - -T. lipovskyi
(black-capped chickadee)

Parus bicolor- - - - -T. whartoni
(tufted titmouse)

Turdus migratorius- - - - -T. sylvilagi
(robin)

Aves (Continued)

Passeriformes (continued)

<u>Sturnella neglecta</u> - - - - -	<u>T. lipovskyi</u>
(western meadowlark)	
<u>Richmondia cardinalis</u> - - - - -	<u>T. lipovskyi</u>
(cardinal)	<u>T. sylvilagi</u>
	<u>T. whartoni</u>
<u>Junco hyemalis</u> - - - - -	<u>T. harperi</u>
(blue-colored junco)	<u>T. sylvilagi</u>
	<u>T. whartoni</u>
<u>Zonotrichia albicollis</u> - - - - -	<u>T. whartoni</u> *
(white-throated sparrow)	
<u>Zonotrichia querula</u> - - - - -	<u>T. whartoni</u>
(Harris' sparrow)	
<u>Melospiza melodia</u> - - - - -	<u>T. lipovskyi</u>
(song sparrow)	

Mammalia

Marsupialia

<u>Didelphis marsupialis virginiana</u> - - - - -	<u>T. lipovskyi</u>
(Virginia opossum)	

Insectivora

<u>Blarina brevicauda</u> - - - - -	<u>T. lipovskyi</u>
(shorttail shrew)	
<u>Cryptotis parva</u> - - - - -	<u>T. sylvilagi</u>
(least shrew)	

Mammalia (Continued)

Lagomorpha

<u>Ochotona princeps</u> - - - - -	-T. <u>harperi</u>
(pika)	T. <u>microti</u>
<u>Lepus californicus</u> - - - - -	-T. <u>lipovskyi</u>
(blacktail jackrabbit)	
<u>Sylvilagus floridanus</u> - - - - -	T. <u>lipovskyi</u>
(eastern cottontail)	T. <u>whartoni</u>
	T. <u>sylvilagi</u> *

Rodentia

<u>Citellus lateralis</u> - - - - -	-T. <u>harperi</u>
(golden-mantled squirrel)	T. <u>subsignata</u>
<u>Tamiasciurus hudsonicus</u> - - - - -	-T. <u>browni</u>
(red squirrel)	T. <u>harperi</u>
<u>Sciurus carolinensis</u> - - - - -	-T. <u>lipovskyi</u>
(eastern grey squirrel)	T. <u>whartoni</u>
<u>Sciurus niger</u> - - - - -	T. <u>whartoni</u>
(eastern fox squirrel)	T. <u>lipovskyi</u>
<u>Sciurus carolinensis</u> and <u>s. niger</u> 15	T. <u>sylvilagi</u>

 15 Skins of both species from which this chigger was
 taken were mixed.

<u>Reithrodontomys fulvescens</u> - - - - -	-T. <u>whartoni</u>
(fulvous harvest mouse)	
<u>Reithrodontomys megalotus</u> - - - - -	-T. <u>autumnalis</u>
(western harvest mouse)	T. <u>lipovskyi</u>
	T. <u>loomisi</u>

Mammalia (continued)

Rodentia (continued)

<u>Peromyscus leucopus</u> - - - - -	-T. <u>lipovskyi</u>
(white-footed mouse)	T. <u>sylvilagi</u>
	T. <u>whartoni</u>
	T. <u>richmondi</u>
<u>Peromyscus maniculatus</u> - - - - -	T. <u>browni</u>
(deer mouse)	T. <u>harperi</u>
	T. <u>lipovskyi</u>
	T. <u>loomisi</u>
	T. <u>sylvilagi</u>
	T. <u>whartoni</u>
<u>Sigmodon hispidus</u> - - - - -	-T. <u>lipovskyi</u>
(hispid cotton rat)	
<u>Neotoma cinerea</u> - - - - -	-T. <u>autumnalis</u>
(bushytail woodrat)	T. <u>finleyi</u>
	T. <u>harperi</u>
	T. <u>microti</u>
<u>Neotoma floridana</u> - - - - -	-T. <u>lipovskyi</u>
(eastern woodrat)	T. <u>sylvilagi</u>
<u>Neotoma mexicana</u> - - - - -	T. <u>harperi</u>
(Mexican woodrat)	
<u>Neotoma micropus</u> - - - - -	T. <u>lipovskyi</u>
(southern plains woodrat)	
<u>Phenacomys intermedius</u> - - - - -	T. <u>harperi</u>
(mountain phenacomys)	T. <u>microti</u>

Mammalia (continued)

Rodentia (continued)

<u>Clethrionomys gapperi</u> - - - - -	<u>T. harperi</u>
(boreal redback vole)	
<u>Microtus longicaudus</u> - - - - -	<u>T. browni</u>
(longtail vole)	<u>T. harperi</u>
	<u>T. microti</u>
<u>Microtus montanus</u> - - - - -	<u>T. harperi</u>
(mountain vole)	<u>T. microti</u>
<u>Microtus ochrogaster</u> - - - - -	<u>T. autumnalis</u>
(prairie vole)	<u>T. lipovskyi</u>
	<u>T. sylvilegi</u>
	<u>T. whartoni</u>
<u>Microtus pennsylvanicus</u> - - - - -	<u>T. autumnalis</u>
(meadow vole)	<u>T. harperi</u> *
	<u>T. whartoni</u>
<u>Microtus richardsoni</u> - - - - -	<u>T. microti</u> *
(Richardson' vole)	
<u>Microtus (Pitymys) pinetorum</u> - - - - -	<u>T. lipovskyi</u>
(pine vole)	
<u>Rattus norvegicus</u> - - - - -	<u>T. lipovskyi</u>
(Norway rat)	
<u>Mus musculus</u> - - - - -	<u>T. lipovskyi</u>
(house mouse)	<u>T. loomisi</u>
	<u>T. whartoni</u>

Mammalia (continued)

Rodentia (continued)

<u>Zapus hudsonius</u> - - - - -	- <u>T. browni</u>
(meadow jumping mouse)	<u>T. harperi</u>
	<u>T. sylvilagi</u>
<u>Zapus princeps</u> - - - - -	- <u>T. harperi</u>
(western jumping mouse)	<u>T. microti</u>
	<u>T. subsignata</u>

Carnivora

<u>Canis latrans</u> - - - - -	- <u>T. lipovskyi</u>
(coyote)	

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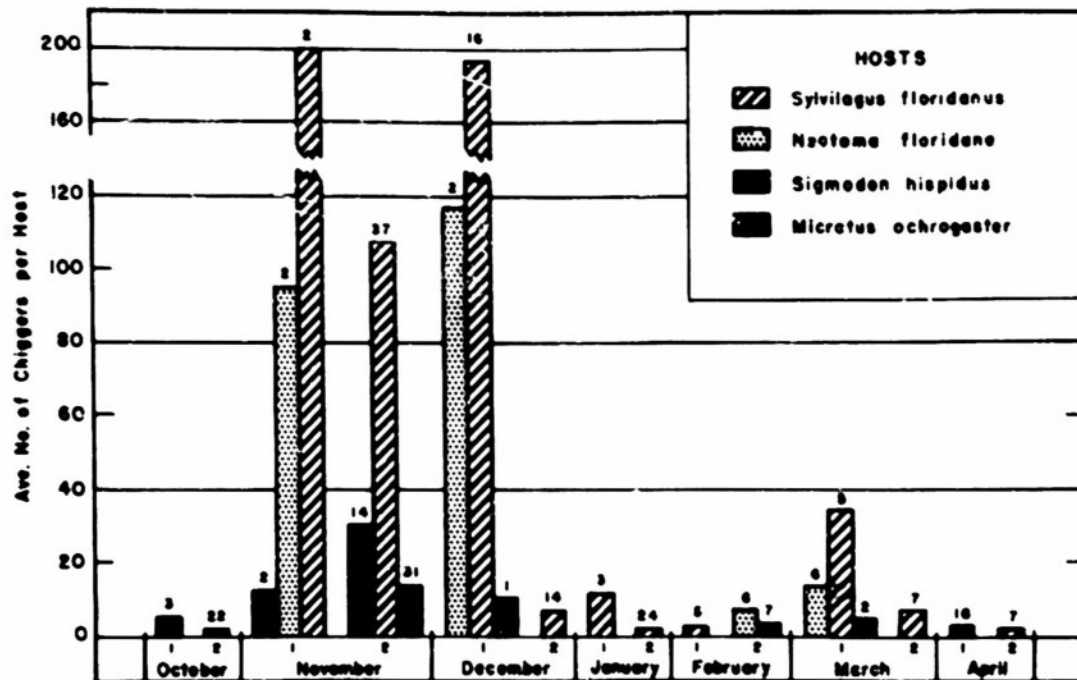
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Figure 1. The total number of larval T. lipovskyi recovered per host examined, in each one-half month period from 1947 to 1952 in northeastern Kansas. The number above each bar is the total number examined during that period.

Figure 2. The estimated number of larval T. sylvilagi per square foot, based on larvae taken on chigger samplers, at the University of Kansas Natural History Reservation.

TROMBICULA (NEOTROMBICULA) LIPOVSKYI



TROMBICULA (NEOTROMBICULA) SYLVILAGI

