

POTENTIAL VECTORS AND RESERVOIRS OF HEMORRHAGIC FEVER IN KOREA¹

By

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INTRODUCTION

Since the spring of 1951 United Nations troops in Korea have had over 2,000 cases of hemorrhagic fever. This disease is undoubtedly the same clinical entity encountered by the Japanese Army in Manchuria and by the Russians in Siberia and named by them, respectively epidemic hemorrhagic fever (1, 2) and hemorrhagic nephroso-nephritis (3, 4). Both the Japanese and Russians believed the disease to be transmitted by arthropods with field rodents as reservoirs. During investigations dealing with the epidemiology and etiology of hemorrhagic fever in Korea in 1952, the findings implicated a group of arthropods as potential vectors of this disease.³

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² The current investigations were greatly facilitated by the wholehearted cooperation of the Far East Command, particularly the Office of the Surgeon, Eighth Army, the 406th Medical General Laboratory and the 8228th Mobile Army Surgical Hospital (later the 48th Surgical Hospital (Mobile Army)). Facilities for the identification of the potential mammal reservoirs were kindly extended by the United States National Museum.

³ A research team sent by the Armed Forces Epidemiological Board, Office of the Surgeon General, was in Korea from April 30 to July 9, 1952. This team, under the direction of Dr. J. E. Smadel and consisting of Dr. Kenneth

These arthropods are ground-inhabiting species of limited mobility, such as chiggers, mites, fleas and ticks, which are ectoparasites of indigenous field rodents. This report presents in some detail ecological studies on several areas in which soldiers contracted hemorrhagic fever.

The vector of hemorrhagic fever is as yet unknown. Russian investigators have speculated that fleas may be the most likely vector in Siberia (5). On

Smithburn, a virologist, Dr. Quentin Geiman, a microbiologist, Dr. Ross Gauld, an epidemiologist and two entomologists (the first two authors of this report), carried out certain studies on the etiology, epidemiology and arthropod phases of hemorrhagic fever. Field headquarters and laboratory were established at the 8228th Mobile Army Surgical Hospital, the Army's Hemorrhagic Fever Center, located about 9 miles northeast of Uijongbu. With the arrival on May 21, 1952, of Captains Lawrence and Harriss and a group of enlisted technicians, the field work was largely taken over and carried on by them until the departure of their unit February 10, 1953. Upon the creation in October, 1952, of the Commission on Hemorrhagic Fever, Armed Forces Epidemiological Board, the Korean group became the Field Unit of that Commission. In mid-November, 1952, the Hemorrhagic Fever Center, later designated as the 48th Surgical Hospital (Mobile Army), and the Field Unit were moved to the outskirts of Seoul. At about this same time the second author returned to Korea as Field Director and the Unit was joined by Dr. Louis J. Lipovsky, who initiated a program of studies on the ecology of chiggers and other ectoparasites. The field work was done in common with the original group and their collecting data up to January, 1953, have been pooled for the purposes of this report.

one occasion, the only recorded arthropod experiment we are aware of, Japanese workers demonstrated that the laelaptid mite, *Laelaps jettmari* Vitzthum, was naturally infected with the etiological agent of hemorrhagic fever (1, 6). The inoculation into a human being of a suspension of 203 *L. jettmari* taken from about 40 wild-caught Manchurian *Apodemus agrarius*, produced a disease which was considered typical hemorrhagic fever and which was transmissible from man to man by inoculation of serum (7). Like the Russians, the Japanese failed to establish or maintain the disease in a common laboratory animal. American efforts to find a suitable laboratory host have also thus far been fruitless (8).

Definitive information on the mode of transmission of hemorrhagic fever to man and the natural cycle of the disease in arthropods and rodents will not be obtained until the etiological agent can be readily handled in the laboratory and used in crucial tests on this phase of the problem. Nevertheless, epidemiological and ecological observations are of definite value in suggesting potential vectors.

The epidemiology of hemorrhagic fever in Korea, and particularly of the cases which occurred in the spring of 1952, has been discussed by Gauld and Craig (9). The known endemic area extends north from the vicinity of Seoul, and very few cases have been reported from the southern part of the peninsula. The great majority of cases were contracted north of the 38th parallel and all the infections have apparently been rural in origin. The disease has consistently exhibited two seasonal peaks of incidence, one in May-June and the other in October-November (8) (see figure 5). Cases have occurred during every month of the year but were at a

low ebb during the early spring, midsummer and winter months. The disease was characteristically sporadic. Even during the spring and fall episodes, nine tenths of the hemorrhagic fever infections occurred as single cases in a unit, being widely separated in time and place and obviously unrelated to one another. However, the other 10 per cent of cases have occurred in small outbreaks of short duration. The infections in such clusters of cases all could have been acquired almost simultaneously and never were followed by other cases. It is significant that these groups of cases were not uniformly distributed throughout the affected company but instead were limited to one or two platoons or squads. They may perhaps be regarded, therefore, as transient, sharply localized, focal episodes which happened to affect several men rather than the usual single individual. There has been no evidence of transmission from person to person and the unequal distribution of cases in the small outbreaks rules out, as a source of the disease, the food and water common to the entire company.

The observed epidemiology of hemorrhagic fever justifies the assumption that it is transmitted by some arthropod and that the reservoir of the disease is not man but some member of the local fauna. Certain features of the epidemiology permit the immediate narrowing of the field of potential vectors, namely: (a) the occurrence of winter cases, which at one stroke virtually eliminates the flying insects; (b) the marked seasonal peaks of incidence in spring and fall; (c) the extreme localization of small outbreaks, which would indicate an arthropod of very limited individual mobility; (d) the transient infectiveness of individual foci; (e) the ability to infect man without leaving evidence as to the site or mode of transmission in

the form of itching or primary lesion. (There is usually lacking in hemorrhagic fever any history or sign of any insect bite whatsoever.)

The arthropods which most nearly fit these characteristics are limited chiefly to certain groups of ectoparasites of animals other than man, namely, ticks, fleas, bloodsucking mites (laelaptids) and trombiculid mites (chiggers). These groups were, therefore, the principal items of our initial program.

Chiggers from the beginning seemed to fit well the observed epidemiology of hemorrhagic fever. There are several striking analogies between the epidemiologies of this disease and scrub typhus, which is known to be transmitted by chiggers. Both diseases are essentially rural, with marked seasonal peaks of incidence, at least in temperate climates, and the distribution is patchy and sharply localized within the endemic areas. Furthermore, the group of chiggers which transmit scrub typhus do not in general cause itching. (The primary lesion or eschar of scrub typhus is a function of the etiological agent rather than of the chigger bite per se.) The analogies between hemorrhagic fever and scrub typhus seem to have escaped notice and we have found no indication that chiggers had received consideration as potential vectors of hemorrhagic fever prior to our arrival in Korea.

Early in our work we learned from Japanese entomologists that many Japanese species of chiggers are active principally in the colder three fourths of the year. The data amassed by Lt. Col. Irvine Marshall⁴ showed that the ectoparasites from Korean rodents included

several species of chiggers throughout the winter. Since chiggers seemed to fit best the role of potential vectors, a point of view which was strengthened as it became apparent that the curve of seasonal abundance corresponded well with that of the incidence of the disease, increasing attention has been paid to this group.

MATERIALS AND METHODS

Three circumscribed areas were selected for more intensive ecological studies because they represented sites where outbreaks of hemorrhagic fever occurred in 1951 and 1952. These sites, at Chip'o-ri, Yoneh'on and Kumhwa in the Iron Triangle region of Korea were under observation during the period of May, 1952, to January 15, 1953. Efforts were made to collect all types of rodents and insectivores, but greatest attention was paid to the following indigenous species: the striped field mouse, *Apodemus agrarius manchuricus*; the reed vole, *Microtus fortis pelliceus*; the Korean redbacked vole, *Clethrionomys rufocanus regulus*; and the Korean hamster, *Cricetulus triton nestor*. These particular rodents were selected because of their abundance, their frequent infestation with ectoparasites, and because the absence of the disease in ^{urban} rural areas minimized the importance of introduced or domestic rodents such as *Mus* and *Rattus*. *Mus* was the second most abundant mammal collected, but very seldom carried ectoparasites.

Box traps and snap traps, for capturing animals alive or dead, were set out

Marshall, and has been carried on more or less continuously by that group up to the present. The data based on these collections, which were made available to us throughout our work relate for the most part to areas other than those studied by us, and will be reported by Lt. Col. Marshall elsewhere.

⁴ The collection of Korean field rodents and their ectoparasites was initiated in August, 1951, by the Preventive Medicine Section of the Office of the Surgeon, Eighth United States Army, under the direction of Lt. Col. Irvine H.

overnight 2 or 3 times per week, so that each study area was trapped almost weekly. The traps were examined in the evening and early morning in an effort to secure live or recently killed animals. The mammals generally were placed individually in bags but sometimes were pooled by species in bags. In the laboratory the bags were sprayed briefly with insecticide by means of an aerosol bomb. The fur of the rodents and insectivores was brushed with cotton moistened by ether. Fleas and blood-sucking mites, which were stupefied by the treatment, were easily collected from the bags containing the host or from the animals themselves. Each animal was then examined under a dissecting microscope, particular attention being paid to the inner and outer ear surfaces and the perineum, which are preferred sites of attachment for trombiculids. The numbers and sites of attachment of chiggers were recorded in each instance, in order to determine if there were any species preference as to site of attachment.

In the period December 1, 1952, to January 15, 1953, in half the instances the washing method of Lipovsky (10) was employed in collecting chiggers from hosts. The two methods were compared directly by first counting the chiggers in the ears of the host and then noting how many chiggers were collected from those same animals by the detergent-washing method. It was found that the Lipovsky technique resulted in the collection of about 10 per cent more chiggers than the first method.

The chiggers from a group of rodents of the same species collected in one specific locality were often pooled. The trombiculid mites were preserved in 70 per cent alcohol unless they were to be used in studies on the isolation of the etiological agent of hemorrhagic fever, or for rearing purposes. The chiggers

were mounted in Berlese's medium or methocellulose medium. Efforts were made to mount samples of 25 chiggers from each collection, but in the summer months chiggers were too scarce to make this possible. There were 165 samples employed in this study, and of these, 92 consisted of 25 chiggers each. In the remaining instances, all available specimens were mounted. Laelaptid mites were mounted in methocellulose; fleas were cleared in caustic potash, dehydrated in alcohol and mounted in balsam. Study skins and skulls were prepared from samples of the mammals collected.

Ectoparasite indices are calculated as arithmetic means, where the numerator is the total number of a particular category of ectoparasites, and the denominator is the total number of a given category of host. The denominator is equivalent to noninfested plus infested hosts.

The laelaptid mites were determined by Captain Hugh L. Keegan, of the Department of Entomology, Army Medical Service Graduate School, and by Dr. E. W. Jameson, Jr., of the 406th Medical General Laboratory. Miss Mary Lou Morrow and Dr. Douglas J. Gould of the Department of Entomology, Army Medical Service Graduate School, assisted Lt. Col. Robert Traub in the identification of the trombiculid mites, and the fleas were identified by the last named. The mammal identifications were made by Mr. William H. Lawrence.

RESULTS

Ticks. Ticks were collected on small rodents on 33 occasions and most of these were from *Apodemus*, *Cricetulus* or *Clethrionomys* in the endemic regions. All these ticks were immature and hence could not be determined beyond the genus. Immature *Ixodes* were collected on 29 occasions and *Haemaphysalis* on

four. One adult specimen of *Haemaphysalis bispinosa* Newmann, 1897, was collected by dragging vegetation with a burlap flag.

In Korea, we obtained no history of ticks found on man. Ticks have been so uncommon that they seem not to warrant serious consideration as potential vectors.

Fleas. Fleas have been too scarce to warrant tabulation. For example, during the first week in October only 19 fleas were collected on 79 mammals of all types. A subspecies of *Ctenophthalmus congener* was at times found on *Apodemus*, *Microtus*, *Clethrionomys*, *Cricetulus*, *Mus* and *Rattus* throughout the year. With the onset of cool weather in October, *Neopsylla bidentatiformis* (Wagner, 1893) was frequently taken on most of these hosts, along with *Stenoponia sidimi* Marikovski, 1937. Four species of rodent fleas were taken only in the fall. These were: *Rhadinopsylla insolita* Jordan, 1939, *Monopsyllus anisus* Rothschild, 1907, a subspecies of *Peromyscopsylla hamifer* (Rothschild, 1906) and a new species of *Neopsylla*. A species of *Palaeopsylla* and *Doratopsylla coreana* Darskaya, 1949, were collected from shrews in the autumn.

The relative scarcity of fleas together with the lack of marked variation in seasonal incidence place this group among the less likely of the potential vectors.

Laelaptid mites. 1. SEASONAL ABUNDANCE. The laelaptid mites were fairly common ectoparasites of the indigenous rodents in the 3 hemorrhagic fever areas surveyed. The most abundant species encountered were: *Laelaps jettmari* Vitzthum, 1930, *Eulaelaps stabularis* (Koch, 1839), *Haemolaelaps glasgowi* (Ewing, 1925), *Neoichoronyssus carnifex* (Koch, 1839) and *Haemogamasus japonicus* Asanuma, 1951. The monthly

average number of laelaptid mites per *Apodemus agrarius* did not show any significant seasonal variations, as can be seen from figure 1. The maximum laelaptid index for *Apodemus agrarius* was reached in January but the minimum index had occurred a month earlier. The erratic graph suggests a fortuitous combination of circumstances. The monthly indices for the various species of laelaptids in figure 1 show that none of these mites exhibited any marked seasonal peaks in the spring and fall. *E. stabularis* was most abundant in the period May through early July and was at a minimum in November. *N. carnifex*, on the other hand, was most abundant in October. *L. jettmari* was prevalent throughout the year.

2. HOST RELATIONSHIPS. As shown in figure 2, while two thirds of the laelaptids taken on *Apodemus agrarius* were *L. jettmari*, this mite was never collected on *Microtus*, *Clethrionomys* or *Cricetulus*. (This laelaptid, however, was occasionally collected on *Apodemus peninsulae*, and on *Micromys minutus*.) Ninety-three per cent of the *E. stabularis* occurred on *Apodemus agrarius*, while nearly two thirds of the *H. glasgowi* were from *Microtus*. Ninety-four per cent of the laelaptids on *Cricetulus* were *N. carnifex*. *Clethrionomys* very rarely carried laelaptids.

3. POSSIBLE RELATION TO HEMORRHAGIC FEVER. The single reported isolation of the etiological agent of hemorrhagic fever from wild-caught *Laelaps jettmari* (1, 7) may very well represent the harboring of the agent by an ectoparasite which has fed on the body fluids of an infected rodent, analogous to the isolation of plague from the lice of rodents in the western United States. The present data fail to indicate a correlation between the abundance of any laelaptid mite and the spring and fall peaks of

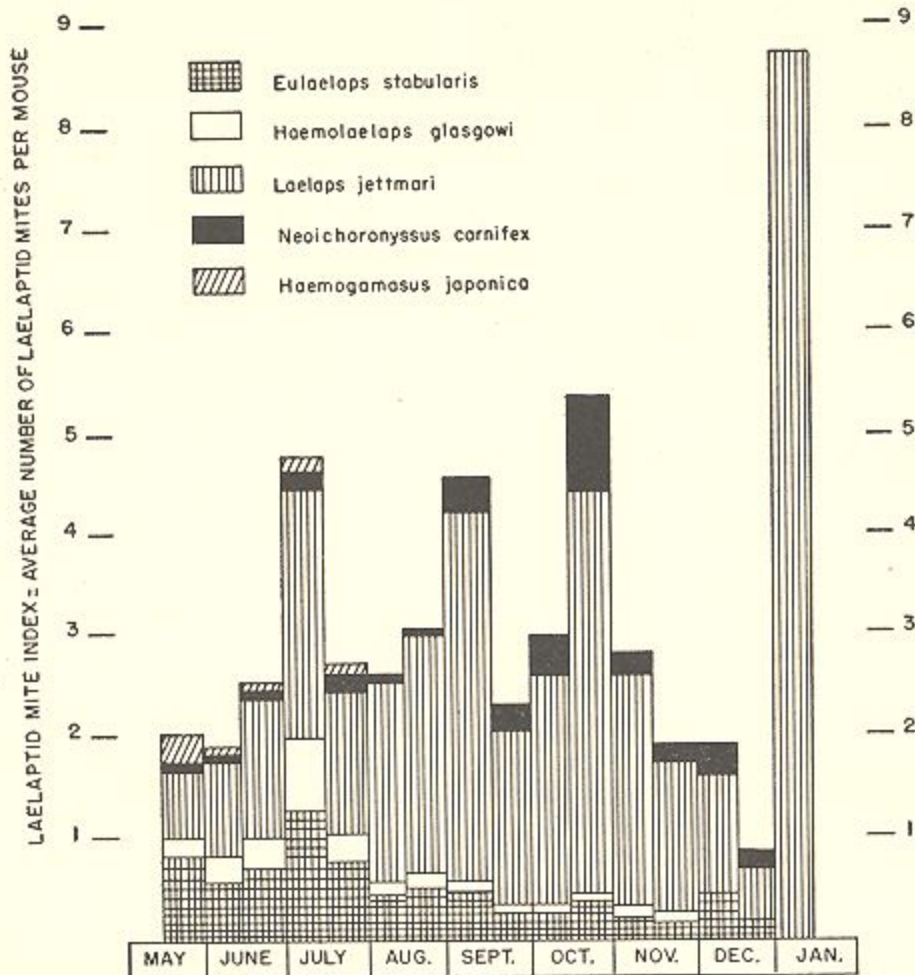


FIGURE 1. Laelaptid mite index, or average number of laelaptids of all species per striped field mouse, *Apodemus agrarius*, collected in 3 known hemorrhagic fever areas in Korea, May 1, 1952, to January 15, 1953.

hemorrhagic fever. None of the laelaptid mites collected are known to bite man and their actual food is unknown in most instances. Most of them, including *L. jettmari*, apparently do not feed on the blood of the rodents from which they are collected. These laelaptids range over much of Asia and Europe and in Korea they were just as common in military camps which were apparently free of infection as in the endemic area. It is conceivable that laelaptids could serve as vectors under circumstances which bring troops in

close contact with rodents and their nests, as during the construction of a bunker. Such a mode of transmission might account for certain cases of hemorrhagic fever but it seems an unlikely explanation for the overall observed epidemiological pattern.

Trombiculid mites (chiggers). 1. SEASONAL ABUNDANCE. The chiggers of North Korean rodents exhibit a striking seasonal periodicity in abundance, with the population peaks occurring in the spring and fall. Figure 3 shows the average number of chiggers of all species

found on the striped field mouse, *Apodemus agrarius*, collected in the 3 areas studied. The figure is based on a total of 1,026 *Apodemus*, and 2,344 chiggers examined out of a total of 9,065 preserved. The chigger index (average number of trombiculids per mouse) was 15 for the first 2 weeks of May, and dropped rapidly thereafter so that by the end of June the index was 1, while during July and August it was even lower. The average number of chiggers

per *Apodemus* started to rise in late August and by the end of September the index was 30. By mid-October the index had reached a maximum, with an average of 80 chiggers per striped field mouse. The index remained high through November but fell rapidly during December, reaching 11.3 by mid-January. Preliminary data indicate that during the last 2 weeks of January, there was an average of 4 chiggers on each of 10 *Apodemus*.

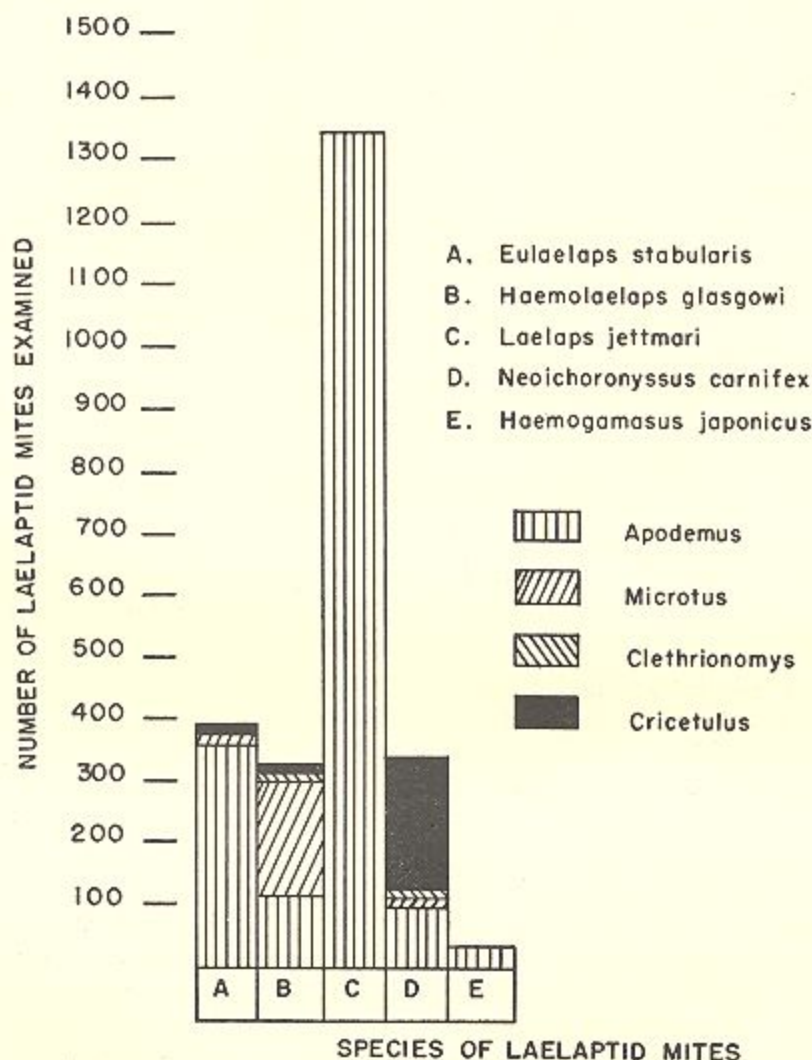


FIGURE 2. Laelaptid mites found on 4 species of mice in 3 hemorrhagic fever areas in Korea, May 1, 1952, to January 15, 1953.

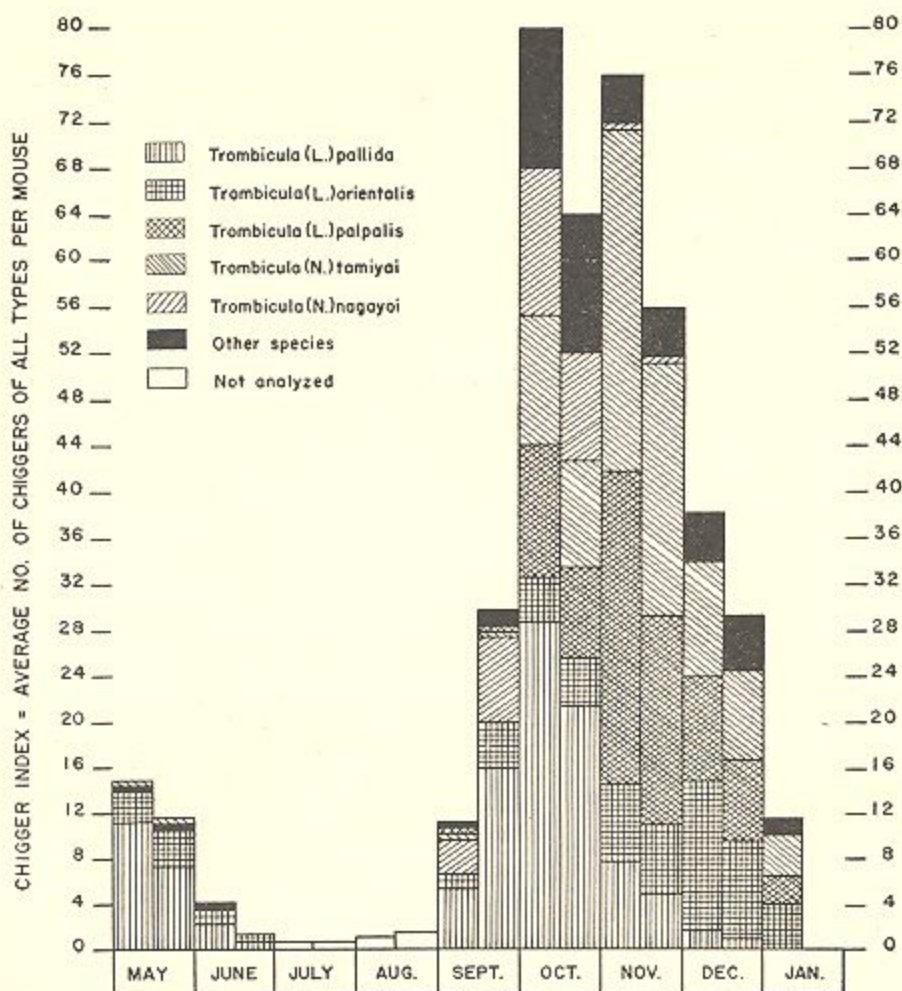


FIGURE 3. Chigger index, or average number of chiggers of all species per field mouse, *Apodemus agrarius*, collected in 3 known hemorrhagic fever areas in Korea, May 1, 1952, to January 15, 1953.

The same general seasonal trend is shown by the chiggers of the reed vole, *Microtus fortis*, although the data suffer from the inadequacy of the numbers of these hosts collected, viz., 118 animals, and 807 chiggers identified out of 2,588 preserved. In early June the index was 17, but in July and August it ranged between 0 and 3.8. By September the average had increased to 185 chiggers per *Microtus*. In early November each of 8 specimens of *Microtus* carried an average of over 1,000 chiggers but in December the index dropped to 153.

The numbers of *Apodemus agrarius* and *Microtus* captured in the studied areas and the percentage of those infested with chiggers are given in table 1. There is a general relationship between the chigger index and the proportion of hosts which were infested. When the index was high almost every animal carried chiggers but very few were infested during the summer months when the index was low.

Clethrionomys rufocanus, the red-backed vole, and *Cricetulus triton*, the Korean gray hamster, were collected too

TABLE I

Percentage of *Apodemus agrarius* and *Microtus fortis* infested with chiggers in 3 hemorrhagic fever areas, Korea, May 1, 1952, to January 15, 1953

Month	<i>Apodemus agrarius</i>		<i>Microtus fortis</i>	
	No. of mice examined	Per cent of mice infested	No. of mice examined	Per cent of mice infested
May	56	80	13	38
June	161	24	25	30
July	110	11	4	25
August	224	43	13	69
September	104	89	14	93
October	104	99	17	100
November	181	95	21	100
December	53	95	7	100
January	33	94	4	100
Totals	1,026		118	

infrequently to warrant calculating their chigger indices. However, the number of chiggers per animal was again at a minimum during the summer months although for both of these hosts the numbers were higher than those for *Apodemus* and *Microtus*, i.e., a total of 64 chiggers on 3 hamsters in July, 220 on 6 *Clethrionomys* in June and an average of 261 on each of 6 *Cricetulus* in September.

As shown in figure 3, *Trombicula* (*Leptotrombidium*) *orientalis* (Schluger, 1948) was well represented on *Apodemus agrarius* in the spring, was found in small numbers through the summer, but constituted 45, 57 and 24 per cent of all chiggers in June, July and August, respectively, and increased slowly in the fall to reach a peak in December. *Trombicula* (*L.*) *pallida* was the most abundant of the spring chiggers, with small numbers in summer (19 and 20 per cent of all chiggers in July and early August), increased rapidly in late August and September to a peak in October, and declined

sharply in November to a very low level in December. *T. (L.) palpalis* (Nagayo et al., 1919) was noted only in the fall months and, along with *Trombicula* (*Neotrombicula*) *tamiyai* Philip and Fuller, 1950, was the most prevalent species in November.

The data in figure 3 refer only to the trombiculids on *Apodemus agrarius*, but when the data were consolidated for *A. agrarius*, *Microtus*, *Clethrionomys* and *Cricetulus*, essentially the same monthly distribution of chiggers was observed as in figure 3. The integrated data disclose that whereas only 7 per cent of the chiggers in October were *T. orientalis*, 24 per cent of all the trombiculids collected in November were of this species. Forty per cent of the chiggers collected in October were *T. pallida*. The undescribed species of the subgenus *Leptotrombidium* herein referred to as "ZZ" was most common during June and July, when 32 per cent and 56 per cent of all the trombiculids taken were of this species. Seventy-nine per cent of the *T. (N.) japonica* were collected in October, and none were taken during the spring or summer.

2. HOST RELATIONSHIPS. To a great extent, the 4 species of indigenous rodents studied share the trombiculid mite fauna, although certain chiggers are characteristically found more frequently on some hosts. This is shown in figure 4. *Apodemus agrarius* carried the greatest number of species of chiggers, with *T. pallida* constituting 31 per cent of all specimens examined from this host, and *T. orientalis*, 17 per cent. *T. orientalis* and the undescribed *Leptotrombidium* referred to here as "ZZ" were common on *Clethrionomys*. *T. pallida* and *T. tamiyai* were the most abundant species on *Microtus* and, in fact, 35 and 42 per cent, respectively, of the totals of these two species were collected

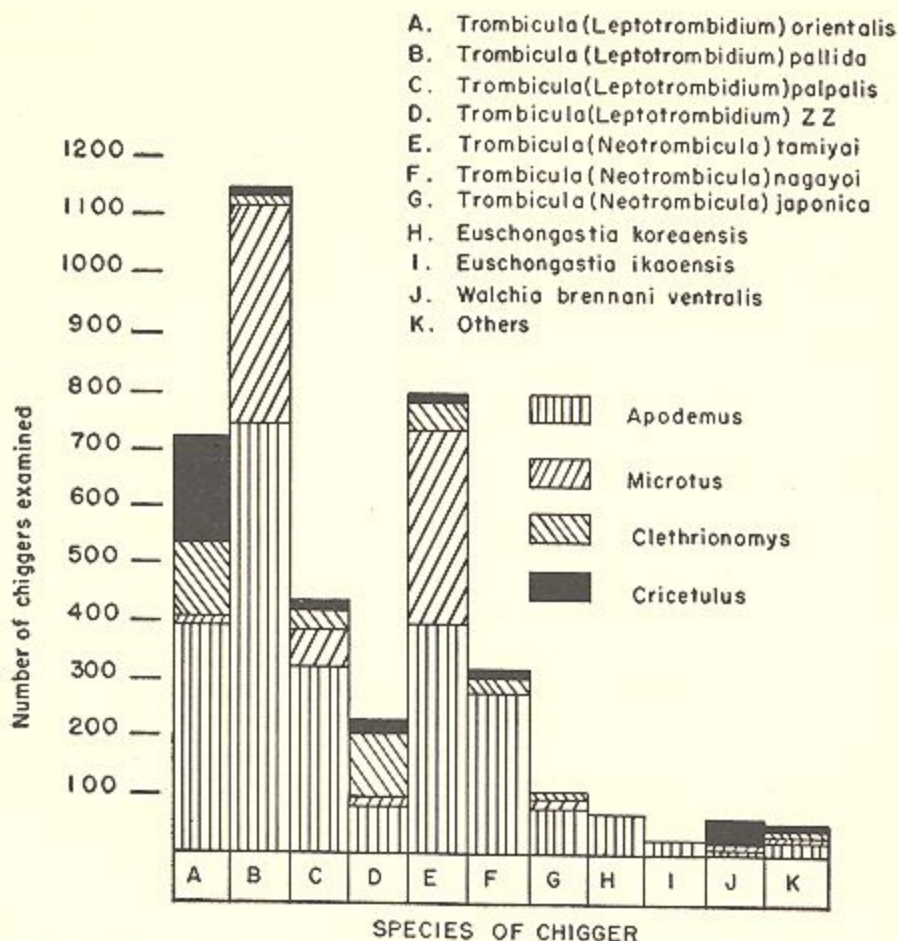


FIGURE 4. Trombiculid mites (chiggers) found on 4 species of mice in 3 hemorrhagic fever areas in Korea, May 1, 1952, to January 1, 1953.

from this reed vole. It is considered likely that *Microtus* frequents the ecological habitats best suited for these species of chiggers. It is interesting to note that less than 1 per cent of the *T. orientalis* were taken from *Microtus*, but virtually three fourths of the chiggers found on the gray hamster, *Cricetulus*, were of this species.

3. GEOGRAPHICAL DISTRIBUTION. Essentially the same species of chiggers were taken in all 3 infested areas. At Chip-ori, *T. pallida* was the dominant form, either because of the abundance of *Microtus* or because this species of chig-

ger is particularly prevalent in the grassy stream-sides preferred by the reed vole. *T. pallida* was the least abundant at Yonch'on, the location where *Microtus* was never taken.

Although field work south of the 38th parallel was limited in scope during these investigations, our records demonstrate the presence there of certain of the above chiggers. For example, in the Central National Forest, 15 miles north of Seoul, 131 trombiculids from *Apodemus* included 114 *T. orientalis*, 9 *T. pallida* and 8 *Neotrombicula*. In the vicinity of Seoul, these trombiculids

were most readily found on mice trapped on the scrub-covered hillsides or remnants of the northern forests.

4. MISCELLANEOUS OBSERVATIONS. The various species of trombiculid mites usually showed a predilection for certain sites of attachment on the host. Four hundred and fifty-nine of the chiggers examined were noted as having been attached to the perineal region, while 2,301 had been attached to the ear. Seventy-four per cent of the chiggers of the subgenus *Neotrombicula* were attached to the perineum. All 3 species of *Neotrombicula* were apparently equally prone to attach to such sites. Fourteen per cent of the perineal specimens were *T. pallida*, while only 1 per cent were *T. orientalis*. The vast majority of *T. orientalis*, *T. pallida* and *T. palpalis* (84 to 95 per cent) were collected from the ears of the host.

In addition to the chiggers listed in figure 4, the following trombiculids were collected in the endemic area: 12 specimens of *Trombicula* (*Leptotrombidium*) *subintermedia* Jameson and Toshioka, mainly from *Apodemus*, 21 specimens of an undescribed *Leptotrombidium* from the same host, and one individual of a new species of the subgenus *Trombiculindus*, also from *Apodemus*.

5. ROLE OF CHIGGERS AS POTENTIAL VECTORS OF HEMORRHAGIC FEVER. If it is assumed that an arthropod is the vector of a disease characterized by two marked seasonal peaks, a phenomenon consistently exhibited by hemorrhagic fever in the experience of Japanese (1), Russians (5) and Americans (8), it is reasonable to expect some correlation between the incidence of the disease and the seasonal abundance of potential vectors. This should hold with particular force when the disease has one of its low points in

midsummer when the activity of many arthropods is greatest. Of the arthropod groups which have been considered potential vectors, chiggers, with their bimodal peaks, correspond fairly well with the disease, while none of the other groups show any such correlation.

The data for 1952 plotted in figure 5 show that the sharp decrease of chiggers in June was followed by a decline of the disease in July and that the chigger increase which began in late August and reached a peak in October was followed by the rise in cases from September to the peak in November. (It may be remarked that in 1953 chiggers which were at a very low level in January and February increased rapidly in number in March to a peak in April and, as in the previous year, declined sharply in June. The spring episode of hemorrhagic fever cases began in April with the peak in late June or early July.) The period of incubation, not definitely determined but with known extremes of 7 and 39 days, has been considered (9) to average probably 2 or 3 weeks.

In the absence of a susceptible laboratory animal and the consequent impossibility of carrying out transmission experiments, it is somewhat hazardous to speculate about individual species of potential vectors. It may be remarked, however, that *T. pallida* is the chigger species which most closely fits the curve of hemorrhagic fever incidence with due allowance for a period of incubation.

Certain analogies between hemorrhagic fever and scrub typhus have been mentioned above. The epidemiology of scrub typhus is, of course, related to the geographic and seasonal distribution, habits and life history of chiggers. In regard to the spotty distribution of the disease, it is known

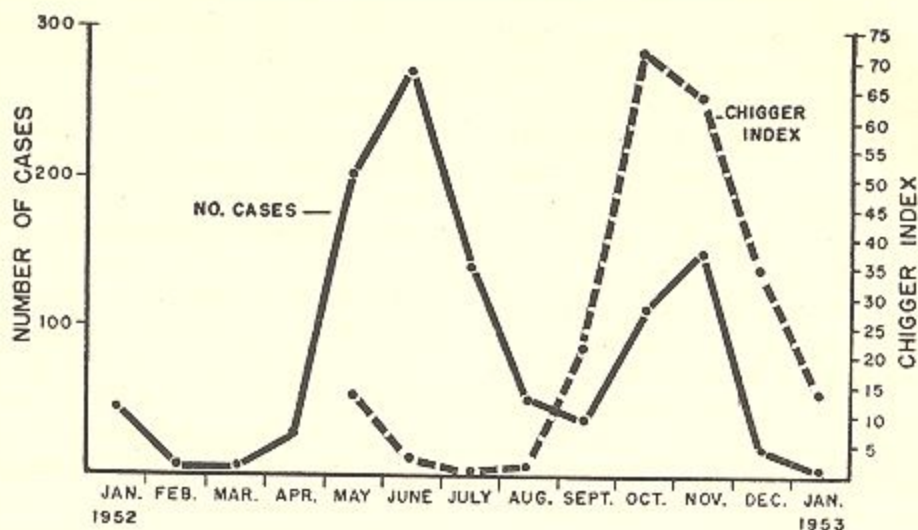


FIGURE 5. Hemorrhagic fever cases and average number of chiggers per field mouse (*Apodemus agrarius*) in Korea.

that chiggers may be extremely abundant in a very circumscribed area while they may be scarce or absent only 3 feet away (11). Focal outbreaks have occurred in groups of men simultaneously exposed to localized "chigger islands" or "typhus islands" while others in the same general vicinity escaped infection (12). Larval chiggers, the only parasitic stage in the life history, do not wander more than a few feet from their birthplace. It is therefore possible to have individual broods concentrated within a few square yards emerging at about the same time. Since the larvae normally feed only once, active larvae from any given brood would disappear from that spot in a relatively short time. A situation of this sort could account for the generally sporadic incidence of hemorrhagic fever and, in particular, for the localized outbreaks not followed by other cases.

It is perhaps sufficient for the present to point out the following: (a) throughout the endemic area chiggers of one species or another are present through-

out the year, often in great abundance; (b) the life history of chiggers in general, together with the seasonal periodicity of some of the species and, in any case, of the group as a whole, can be correlated with the incidence of the hemorrhagic fever; (c) no other likely candidates seem to fit well into the epidemiological picture.⁵

Rodents and other mammals. As mentioned earlier, 4 indigenous rodents were collected often enough to provide adequate ectoparasite data. These were: the striped field mouse, *Apodemus agrarius manchuricus* Thomas; the reed vole, *Microtus fortis pelliceus* Thomas; the Korean red-backed vole, *Clethrionomys rufocanus regulus* Thomas; and the Korean gray hamster, *Cricetulus triton nestor* Thomas. Other small mam-

⁵ Preliminary data indicate that the entomological and epidemiological pattern observed in 1953 (to November) is essentially the same as that reported in this paper. Spring and fall peaks of incidence of hemorrhagic fever have occurred in 1953, and chiggers were abundant in the spring, became very scarce in the summer, and were extremely abundant in the fall.

imals taken in the endemic areas were: the Old World harvest mouse, *Micromys minutus ussuricus* Barrett-Hamilton; the Manchurian wood mouse, *Apodemus peninsulae* Thomas; the house mouse, *Mus musculus mollossinus* Temminck; the brown rat, *Rattus norvegicus* Berkenhout; the Siberian chipmunk, *Tamias sibiricus asiaticus* Gmelin; the musk shrew, *Crocidura lasiura lasiura* Dobson, and the lesser white-toothed shrew, *Crocidura suaveolens shantungensis* Miller.

The striped field mouse, *Apodemus agrarius*, was ubiquitous in Korea and was generally the most abundant rodent present, regardless of environment. This mouse occurred in all types of habitat encountered, i.e., agricultural land, abandoned upland fields, scrub-covered hillsides, deciduous forests, mixed deciduous-coniferous forests, river flood plains and streamsides, but was most abundant in abandoned upland grain fields. This mouse was frequently observed in military tents and dugouts. Spring and fall breeding periods were observed.

The reed vole, *Microtus fortis*, was found only in very specialized habitats in two of the study areas, Chip'o-ri and Kumhwa, and these constitute the southernmost records for this vole. In each of these areas it was restricted to a narrow belt paralleling the water's edge, where the soil remained damp and supported a luxuriant growth of grass, weeds and willows. In these specific habitats, *Microtus* was particularly abundant, but the voles were never taken in the drier upland fields immediately adjacent to these areas. Numerous other streamside sites, which appeared to be excellent *Microtus* habitats, were trapped without success, even though they were

within the same general geographic region as the two locations favored by the known colonies. The reed vole was frequently observed foraging about in the grassy runways during the daylight.

The Korean red-backed vole, *Clethrionomys rufocanus*, although essentially a forest-dwelling rodent, in the endemic areas has adapted itself to living on rocky hillsides covered with a heavy scrub growth of pines, oaks, hazels and other brush, where it apparently occurs in limited numbers.

The Korean gray hamster, *Cricetulus triton*, was found to be an inhabitant of rocky hillsides covered with rather dry scrub vegetation. Considerable trapping in deciduous forests, as well as in abandoned agricultural fields, failed to produce any specimens. On the whole, the gray hamster seemed to be a nongregarious animal which was never very abundant in a given locality. Most of our specimens were collected at Kumhwa.

The wood mouse, *Apodemus peninsulae*, appeared to have ecological requirements similar to those of the red-backed vole and was either somewhat more abundant than this vole or else was more readily trapped. Its ectoparasites are not included in the above discussion because of the small number of chiggers and mites collected from this host.

The harvest mouse, *Micromys minutus*, was abundant in the dense stands of grass and weeds bordering the paddy fields where a large number of its nests were seen in the fall. Because the harvest mouse has a habit of traveling about on top of dense vegetation it was difficult to trap.

Of the domestic rodents, *Rattus norvegicus* was limited to the vicinity of former village sites and water courses and was occasionally encountered in

camp sites. The house mouse, *Mus musculus*, was far more abundant than *Rattus* in abandoned fields.

In the light of our current knowledge, no single rodent species can definitely be regarded as a primary reservoir of hemorrhagic fever. Japanese workers in one instance demonstrated that serum from a patient with hemorrhagic fever induced an inapparent infection in an *Apodemus agrarius*, and that tissues from this animal, taken 25 days after inoculation, were capable of transmitting the disease to a volunteer (7, 1). For this reason the Japanese have considered the striped field mouse a potential reservoir. Russian investigators have speculated that *Microtus fortis* (which they referred to as *Microtus michnoi*) may serve as a reservoir (5). The range of this vole, as well as that of *Micromys minutus*, essentially corresponds with the known endemic area in eastern Asia but localized outbreaks have occurred in areas in Korea where one or both of these rodents have not been collected. The essentially rural distribution of hemorrhagic fever implicates indigenous field rodents rather than domestic species such as *Rattus* and *Mus*, in the epidemiology of the disease. Practically all of these rodent hosts can carry most of the ectoparasites mentioned, and might best be considered vehicles for arthropods which are potential vectors of hemorrhagic fever.

SUMMARY

In connection with studies on hemorrhagic fever in Korea, a survey was made of the ectoparasites of indigenous rodents trapped in 3 known endemic areas. Data are presented which indicate that trombiculid mites (chiggers), laelaptid mites, fleas, and ticks may all

be regarded as potential vectors, but that chiggers alone can be correlated with the epidemiology of the disease. Potential reservoirs are more likely to be found among certain field rodents or other mammals rather than among domestic rats and mice.

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