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CLINICAL AND EPIDEMIOLOGICAL STUDIES ON RICKETTSIAL INFECTIONS

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BY

CHARLES L. WISSEMAN, JR., M.D.
DEPARTMENT OF MICROBIOLOGY
UNIVERSITY OF MARYLAND SCHOOL OF MEDICINE
BALTIMORE, MARYLAND 21201

C. PROGRESS REPORT AND CURRENT STATUS

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C. PROGRESS REPORT AND CURRENT STATUS

1. BACKGROUND

a. As in the past, virtually all of our time this year was spent in research on the ecology of murine typhus, and the findings continue to support our hypothesis that this rickettsiosis deeply involves 1) indoor-dwelling commensal murines or other small mammals (theraphions) which behave as a peridomestic species, such as shrews (Suncus); 2) their ectoparasites such as fleas or lice and 3) hyperendemic minifoci or microfoci, wherein a large proportion of the commensal mammals and fleas and lice in a highly restricted locus such as a single building are naturally infected with Rickettsia mooseri, the etiological agent of murine typhus. We were largely occupied with laboratory investigations in Baltimore this year because the shipping strike in U.S. ports made it impossible for us to send our gear to Australia and Burma for the scheduled field-work. The trip to Burma will take place at the time this contract-application is being reviewed, but the Australia project has been deferred until August or September 1979 at the request of our colleagues in Brisbane.

b. Once again very interesting data were obtained in each of the geographical areas under direct study or from which specimens were received, namely, Ethiopia, Burma, Pakistan, Australia and Baltimore in the first category; and Sarawak, Lebanon and Nepal in the latter. The results are summarized as follows, commencing with our main project, murine typhus.

2. STUDIES ON MURINE TYPHUS

a. Ethiopia

1) General

a) Although field operations in Ethiopia were terminated in 1977 when NAMRU-5 was forced to leave the country, so much material had been collected that we were still busy doing indirect fluorescent antibody (IFA) and direct fluorescent antibody tests (FA) in 1978. The general findings and conclusions reported in our previous Report are still wholly applicable, and indeed, are extended and supported by the new data. Tables 1-3 represent final versions of 3 tables presented last year and are based upon all the specimens at hand. The other tables from Year-5 are either now irrelevant or remain unchanged and will not be discussed anew.

b) Table 1 summarizes the data on FA tests of fleas, lice and mites in Ethiopia, whence it can be seen that of the total of 1759 fleas of all types that were dissected and examined, 1392 were from Rattus, and of these, 9% were infected with R. mooseri. Fleas from other hosts were uniformly negative by these criteria, viz., 245 from Praomys and 122 from Desmomys, Mastomys, Arvicanthis, all of which are murines, and from other hosts like Crocidura shrews. (All the Rattus were Rattus rattus and we saw no R. norvegicus.) The great majority of the fleas from the non-Rattus theraphions were from hosts collected indoors, but many (234 = 63%) were taken from areas where Rattus was absent or exceedingly rare. In our opinion, the marked restriction of infected fleas to Rattus is critical, particularly when it is recalled that 1) in Addis Ababa 118 out of 190 Rattus (all indoors) (62%) were infected with R. mooseri as per IFA tests; 2) in all areas, a total of 512 hosts were examined which were neither Rattus nor Mus musculus, and only 3 (0.6%) were positive, and these were from commensal-type Praomys in houses where Rattus also were present. (It must be emphasized that Mus musculus must be excluded from consideration because of of inadequate data, i.e., 1 of 9 positive by IFA and no fleas available for dissec-

	XENOPSYLLA		LEPTOPSYLLA		ALL			
	CHEOPIS	BANTORUM	SEGNIS	AETHIOPICA	OTHER FLEAS	FLEAS - SUB-TOTALS	LICE	MITES.
RATTUS								
ADDIS, TOWN	3/52 6%	8/78 10%	52/280 19%	-	-	63/410 15%	5/80 6%	0/10
MAKANISSA	0/40	1/53 2%	31/267 12%	-	-	32/360 9%	3/48 6%	0/46
ADDIS, TOTALS	3/92 3%	9/131 7%	88/547 15%	-	-	95/770 12%	8/128 6%	0/56
INTOTO	0/34	0/40	17/348 5%	-	-	17/422 4%	0/37	0/89
KOKA, TOTALS	0/49	0/61	-	-	0/90	0/200	-	0/60
TOTAL FOR RATTUS	3/175 2%	9/232 4%	100/895 11%	-	0/90	112/1392 9%	8/16[illegible] [illegible]%	0/205
PRAOMYS. ALL AREAS	0/28	0/69	0/10	0/132	0/6	0/245	.	-
ALL OTHER HOSTS	0/31	0/39	0/10	-	0/42	0/122	.	-
TOTALS FOR ADDIS ALL HOSTS	3/92 3%	9/131 7%	83/547 15%	-	0/13	95/770 12%	-	-
TOTALS FOR KOKA ALL HOSTS	0/75	0/85	-	-	0/113	0/273	-	-
TOTALS FOR INTOTO ALL HOSTS	0/36	0/68	17/358 5%	0/112	0/6	0/578	.	-
TOTALS - ALL HOSTS AND AREAS	3/234 1%	9/340 3%	100/915 11%	0/132	0/138	112/[illegible] 6%.	8/165 5%	0/20[illegible]

TABLE 1. SUMMARY: NUMBERS OF FLEAS, LICE AND MITES FOUND POSITIVE FOR R. MOOSERI INFECTION IN ETHIOPIA BY DIRECT FA TEST (1976-1977)

Numerator = Number positive. Denominator = Number tested.

tion. The house mouse may very well be important in the ecology of the infection.) Another striking observation was that the rate of infection was significantly higher in Leptopsylla segnis than in Xenopsylla cheopis, the putative vectors, or in X. bantorum (hitherto not incriminated in this rickettsiosis), in the areas where the three co-existed, i.e., in Addis, the figures were 88/547 or 15% for L. segnis and only 3% and 7% for the others, while at Intoto, 5% of the L. segnis were positive and no such Xenopsylla were observed for a total of 79 examined. It is noteworthy that at Koka, in the semidesert at a much lower elevation, and where L. segnis does not occur, all 110 Xenopsylla from Rattus and 50 Xenopsylla from Arvicanthis, Mastomys and Crocidura were apparently free from infection. As reported previously, only 3 of 105 Rattus from Koka were serologically positive. We reiterate that at Koka X. cheopis and X. bantorum were extremely abundant on Arvicanthis in the field, at least 50 times more so than on Rattus in Koka town or in Addis Ababa. It is apparent, then, that neither X. cheopis nor Rattus, by themselves, can account for the presence or prevalence of murine typhus infection in rats. Thus, 1) both the flea and rat are

RATTUS RATTUS			FLEAS				LICE		
ACCESS. NO.	INFECTED	SOURCE	XENOPSYLLA BANTORUM	XENOPSYLLA CHEOPIS	LEPTOPSYLLA SEGNIS	SUBTOTAL	POLYPLAX SPINULOSA	HOPLO-PLEURA	SUBTOTAL
B-93013	3+	MAKAN. BARN			2/20= 10%	2/20= 10%	0/7		0/7
B-93019	2+	AMHARA. HOUSE			1/3 = 33%	1/3 = 33%	0/8	0/2	0/10
B-93028	3+	AMHARA. HOUSE			1/3 = 33%	1/3 = 33%	2/15=13%		2/15=13%
B-93043	2+	AMHARA. HOUSE	2/13=15%		7/16= 44%	8/19= 42%	0/4		0/4
B-93047	2+	ADDIS. HOUSE			3/18= 17%	3/18= 17%	0/9	0/1	0/10
B-88724	POS.	MAKAN. HOUSE	0/1		2/8 = 25%	2/9 = 22%			
B-88736	NEG.	MAKAN. BARN			0/10	0/10	1/2 =50%	0/2	1/4 =25%
B-88750	POS.	AMHARA. HOUSE	2/2=100%	1/2= 50%	2/4 = 50%	5/8 = 63%	0/1	0/1	0/2
B-88751	NEG.	AMHARA. HOUSE	4/4=100%	1/1=100%	5/5 =100%	10/10=100%			
B-88752	NEG.	AMHARA. HOUSE		1/1=100%	1/1 =100%	2/2 =100%			
B-88773	POS.	MAKAN. BARN			2/5 = 40%	2/5 = 40%		0/1	0/1
B-88792	POS.	AMHARA. HOUSE	1/5= 20%	0/5		1/10= 10%		1/1=100%	1/1=100%
TOTALS	9/12=75%		9/25=35%	3/9= 33%	26/93= 28%	36/107=34%	3/46= 7%	1/8= 13%	4/54= 7%

TABLE 2. RESULTS OF IFA TESTS IN WHICH AT LEAST ONE FLEA OR LOUSE WAS POSITIVE FOR R. MOOSERI AND WHERE ANOTHER SPECIES OF ECTOPARASITE WAS ALSO TESTED

Numerator = Number positive. Denominator = Number tested. POS. = Positive for R. mooseri. NEG. = Negative. 1+ to 3+ = Indication of positive titer (not available for 1976). B-93013 et seq. = 1977, remainder = 1976.

abundant in Koka town, where there is a low rate of R. mooseri infection; 2) X. cheopis can be extremely common on wild murines in the absence of known endemicity, as in Koka groves; and 3) there can be a high rate of infection in Rattus when X. cheopis is scarce, as at Addis Ababa. A total of 270 other kinds of fleas were examined, including 90 Echidnophaga new species from Rattus at Koka, but all were negative. The remaining 180 were from native murines, etc., not Rattus.

c) Not only was the infection rate consistently much higher in L. segnis than in X. cheopis and X. bantorum, but this species was far more abundant than the latter at all times of the year. As indicated last time, the "index" (average number of fleas per rat) for X. cheopis was well below 0.7 at Addis shortly after the end of the dry period, the season when these fleas were most prevalent, i.e., 10-50-fold more numerous than in the rainy season. The figures for X. bantorum were slightly higher, viz., 1.4. In contrast, at the same period L. segnis had an index of 5-9 in different parts of Addis Ababa and one of 7 at Intoto. On this basis it might seem that L. segnis was qualitatively and quantitatively more important a vector than either species of Xenopsylla. However, because L. segnis is absent at Koka, some other agent must also be involved in the transmission of R. mooseri. Rat lice deserve serious consideration in this regard (even though we lack such data for Koka). As shown im Table 1, 6% (8/128) of the Polyplax or Hoplopleura lice examined at Addis Ababa were positive by FA. Mesostigmatid mites of Rattus were never found to be infected in 205 dissections.

2) Hyperendemic Foci

a) Previously we presented data strongly indicating the occurrence of hyperendemic foci in highly localized areas of Addis Ababa (town and suburbs). Subsequent observations support the hypothesis that the infection rate in rats and ectoparasites in certain domiciles or buildings (e.g., the barn at Makanissa) was significantly higher than in other locations in the general areas, as suggested by the data in Tables 2 and 3. The figures for both 1976 and 1977 are presented in these tables, which also include additional tests since our last report, and which deal with the infection rate in Rattus and lice and/or fleas when at least one ectoparasite was found positive by FA tests. From these it can be seen that in IFA tests with hosts harboring at least one positive louse or flea, 27 of the 32 Rattus (84%) examined were positive, whereas our data show that the percentage for the other Rattus in the same areas (Addis town, Makanissa suburb and Intoto) was 47%. Specifically, the rates were: Addis town 90% versus 55%; Makanissa 87% versus 72%; and Intoto 33% versus 2%. Thus, if one infected flea or louse was present on the Rattus, the chances of the rat having been infected with R. mooseri seem far greater than if the fleas examined had been negative. However, it might be argued that this is to be expected, in that if the Rattus were positive, then it is quite likely that fleas or lice feeding on it could acquire the rickettsiae, and that is what these figures suggest. Analysis tends to refute that contention. Rats are infected for life, but rickettsemia is transient and apparently only persists for a few days. This alone indicates that recently acquired infection in a single rat could not result in such a high correlation as noted above. Moreover, 19 Rattus from Addis town and suburbs, which were positive by IFA, carried a total of 39 Xenopsylla and 88 L. segnis that were negative by FA test. Also, there were 12 positive Rattus from Intoto which had negative fleas, i.e., there were 190 negative Intoto L. segnis and Xenopsylla. Therefore, since so many positive rats carried fleas lacking R. mooseri, it seems logical that other factors are involved besides infected rats merely carrying positive fleas by virtue of concurrent rickettsemia. Further, as shown in Table 2, when one species of flea was found positive on the host, other species of fleas (if present) also were highly likely to be infected, and the same is apparently true for the Rattus lice. Thus, under those circumstances, in 6 of 12 cases (50%), at least one other species was positive as well, and in 26 of the 39 pools of arthropods containing at least one infected individual, more than 39% of the individuals of that species harbored R. mooseri. In 13 instances, all the members of that species were infected per host. Once, every member tested for 3 species of fleas from an individual rat was positive. There was one other example of infection in all 3 species of fleas on one host, and on one occasion, a rat carried both positive fleas and lice. In these cases of multiple infestation where one species was infected, the over-all percentage of fleas or lice that had R. mooseri ranged from 10% to 100%. Nine of these 12 host Rattus (75%) were naturally infected with R. mooseri.

b) The high rate of infection noted in ectoparasites when any one specimen was found positive is clear from the data in Table 3. There were 136 L. segnis tested from 15 Rattus which carried infected L. segnis, and 53% of the fleas had R. mooseri. There was a high rate of infection in the rat lice, viz., 4 individuals of 4 tested from 4 Rattus in 1976 were positive, but the sampling is inadequate for further discussion. Eighteen of the 20 Rattus (90%) providing these particular infected ectoparasites were themselves positive in IFA tests.

c) These data on R. mooseri in Rattus ectoparasites suggest hyperendemicity in certain foci or at certain times. When an individual louse or flea

RATTUS RATTUS			FLEAS			LICE		
ACCESS. NO.	INFECTED	SOURCE	XENO-PSYLLA	LEPTOPSYLLA SEGNIS	SUBTOTAL	POLYPLAX SPINULOSA	HOPLO-PLEURA	SUBTOTAL
B-93001	3+	MAKANISSA. BARN		12/20 = 60%	12/20= 60%			
B-93017	3+	AMHARA		2/10 - 20%	2/10= 20%			
B-93018	3+	AMHARA		1/3 = 33%	1/3 = 33%			
B-93038	2+	MAKANISSA. BARN		2/20 = 10%	2/20= 10%			
B-93044	2+	AMHARA		1/1 =100%	1/1 =100%			
B-93045	3+	AMHARA		8/11 = 73%	8/11= 73%			
B-93049	3+	MAKANISSA. BARN		2/5 = 40%	2/5 = 40%			
B-93050	1+	MAKANISSA. BARN		4/15 = 27%	4/15= 27%			
B-93271	3+	INTOTO		14/20 = 70%	14/20= 70%			
B-93409	NEG.	INTOTO		1/2 = 50%	1/2 = 50%			
B-93410	NEG.	INTOTO		1/10 = 10%	1/10= 10%			
B-88738	POS.	AMHARA		7/9 = 78%	7/9 = 78%			
B-88739	POS.	AMHARA		10/10 =100%	10/10=100%			
B-88769	POS.	MAKANISSA. BARN		5/10 = 50%	5/10= 50%			
B-88779	POS.	AMAHARA				1/1 =100%		1/1=100%
B-88781	POS.	MAKANISSA. HOUSE					1/1=100%	1/1=100%
B-88782	POS.	MAKANISSA. HOUSE					1/1=100%	1/1=100%
B-88787	POS.	MAKANISSA. HOUSE				1/1 =100%		1/1=100%
B-88791	POS.	AMHARA		6/10 = 60%	6/10= 60%			
TOTALS	18/20=90%			73/136= 53%	73/136=53%	2/2 =100%	2/2=100%	4/4=100%

TABLE 3. RESULTS OF IFA TESTS IN RATTUS AND OF DIRECT FA TESTS IN RAT FLEAS AND LICE IN WHICH ONLY ONE SPECIES OF ECTOPARASITE WAS TESTED AND IN WHICH AT LEAST ONE SPECIMEN WAS POSITIVE FOR R. MOOSERI INFECTION

Numerator = Number positive. Denominator = Number tested. POS. = Positive for R. mooseri. NEG. = Negative. 1+ to 3+ = Indication of positive titer (not available for 1976). B-93001 et seq. = 1977, remainder = 1976.

became infected, a significant proportion of other lice and/or fleas on the same host tended to acquire infection. Moreover, the great majority of rats (27 of 32, or 84%) with infected fleas or lice, themselves had a history of murine typhus infection. This impression is heightened by the fact that two small foci seem to be involved in the bulk of the ectoparasites that provided positive results, namely Amhara's house in Addis and the dairy barn in Makanissa. Thus, of the 32 rats represented in Tables 8 and 9, 28 (88%) came from either of these two places (15 from Amhara's house, and with 13 (87% infected, and 12 from the barn with 10 (83%) infected.) Further, all together (including Rattus with negative fleas or lice), a total of 23 Rattus were collected in Amhara's house in 1977, and 19 (83%) were infected. In 1976 the rate in that domicile was 7/9 = 77%, whereas the rate for other parts of Addis was 58%. An important point is that in 1977 a period was reached when it was impossible to trap rats in Amhara's house for weeks, indicating that either no Rattus remained or they had become too wily to trap. After a lapse of 3 weeks an additional 4 rats were taken, and these were all negative. All in all these observations suggest that these last 4 were recent arrivals that had not yet become demonstrably infected with

R. mooseri. In the barn in the suburbs of Addis in 1976, 94% of the adult Rattus were positive for R. mooseri by IFA. The rates for all Rattus there in 1976 and 1977 respectively were 86% and 77%. Insofar as infected ectoparasites in these particular foci are concerned, there were 31 instances in which one or more such fleas or lice were encountered and 25 (81%) of these concerned either the barn or Amhara's house. Of the 12 instances of multiple occurrence of infected ectoparasites of two or more species, 11 (91%) were from one of these two localities. We are referring to such highly localized areas of hyperendemicity as minifoci.

b. Rangoon

1) When in Rangoon in 1977 as Consultants for the World Health Organization, we started collaborative studies on murine typhus with the Rodent Control Demonstration Unit of W.H.O. Samples of blood from rats and shrews and microdissections of ectoparasites collected at that time were supplemented by material from RCDU. The results, summarized in Tables 4-6, clearly show that Rangoon is an ideal place for intensive studies on murine typhus. For example, no fewer than 5 murines and 1 species of shrew are common and commensal in that city, and significant rates of R. mooseri have been found in all species. Xenopsylla cheopis and X. astia are prevalent on all these theraphions.

SPECIES OF MAMMAL	NUMBER POSITIVE	NUMBER TESTED	% POSITIVE
Rattus rattus	47	172	28%
Rattus exulans	147	740	20%
Rattus norvegicus	35	107	33%
Bandicota bengalensis	216	1329	16%
Bandicota indica	0	1	-
Mus musculus	8	118	7%
Suncus murinus	108	581	16%
Totals	526	3148	16.7% (Aver.)

TABLE 4. Results of survey for antibodies to murine typhus by IFA technique among small mammals in Rangoon, Burma (1975 - June 16, 1978)

2) As shown in Table 4, one-third of the 107 R. norvegicus tested were positive for R. mooseri, with R. rattus showing a 28% rate. The number of Bandicota bengalensis sampled was nearly twice that of the second largest group, R. exulans, and there is no doubt that this large rat is exceedingly common in and near domiciles in Rangoon. Its distinctive burrow-openings are readily seen in dining rooms in hotels, for example. That 16% of the Bandicota bengalensis tested were

positive for R. mooseri seems highly significant. In Bombay, Soman (1950) found that 13% of the B. bengalensis (reported as Gunomys kok) tested were positive at low titers in the complement-fixation (CF) test. Rattus exulans apparently plays a significant role in the ecology of murine typhus in S.E. Asia. The 20% infection rate we report on the basis of IFA tests probably compares well with the 3% rate found by isolation of rickettsiae in Thailand by Sankasuwan et al.,(1969). Marchette (1966), in Malaya, found that only 2% of 41 R. exulans were demonstrably infected by CF test but the single positive specimen came from the only 8 urban R. exulans represented. The results with Suncus in Rangoon (16% positive) are also noteworthy, especially since Marchette (1966) noted that only 2 of 84 shrews (2%) showed signs of R. mooseri infection, by CF tests, and Soman found none positive (by CF) in Bombay, where only 15 shrews were examined. The relatively low rate (7%) in the house mouse, Mus musculus, is of interest since the data on the role of that rodent are equivocal (Traub et al.,*# 1978). Thus, previous reports from elsewhere indicated lack of infection in campestral M. musculus but presumed significant involvement in indoor mice, but only limited observations had been made concerning this species.

3) The results of FA tests with ectoparasites from commensal theraphions in Rangoon are shown in Table 5, whence it can be seen that, as in Ethiopia, only fleas and rat-lice are implicated. The overall figure for fleas (18%) is much higher than that reported for Xenopsylla (1%-3%) in Ethiopia, where even in Addis Ababa, the percentage positive never exceeded 10% (Table 1) for Xenopsylla. The maximum noted in Ethiopia for L. segnis was 15%, but this species has not been found in Rangoon.

ECTOPARASITES	NUMBER POSITIVE	NUMBER TESTED	% POSITIVE
Lice	11	148	7%
Mesostigmatid Mites	0	18	-
Ticks	0	10	-
Chiggers	0	10	-
Fleas	44	239	18%
TOTALS	66	425	Average 15.5%

TABLE 5. Results of tests by Direct Fluorescent Antibody technique for the presence of Rickettsia mooseri in some ectoparasites of small mammals in Rangoon, Burma (1977 - July 1978)

* References marked * are based, wholly or in part, upon work accomplished under this contract or its immediate predecessor.

#References marked # are papers prepared by the contractors or their associates in our Department.

4) We have been assisting the Rodent Control Demonstration Unit in Rangoon in their studies on the fleas of local commensal theraphions, and only two species account for 99% of the specimens collected, namely Xenopsylla cheopis and X. astia. The cat flea, Ctenocephalides felis, and the sticktight flea, Echidnophaga gallinacia, are very occasionally encountered on rodents, and we believe that Acropsylla girshami occurs at times on Mus musculus, probably outdoors and in the dry season. The composition of the Xenopsylla fauna apparently varies with the species of host, as indicated in Table 6, which is based upon our determinations and on data from RCDU, as per a manuscript by Walton et al.# (in preparation) and represents collections from 4411 mammals.

HOST	TOTAL NO.	XENOPSYLLA			
		X. CHEOPIS		X. ASTIA	
		NUMBER	%	NUMBER	%
RATTUS NORVEGICUS	1238	418	34%	820	66%
RATTUS RATTUS	1060	564	53%	496	47%
RATTUS EXULANS	864	704	81.5%	160	18.5%
BANDICOTA BENGALENSIS	13,426	1405	10.5%	12,021	89.5%
SUNCUS MARINUS	569	465	82%	104	18%
(TOTALS)	17,157	3556	21%	13,601	79%

TABLE 6. Numbers and percentages of Xenopsylla cheopis and X. astia fleas found on various hosts in Rangoon (1975-1977)

5) Thus, while it is obvious that both species are found on all five mammals, and while, over-all, X. astia outnumbered X. cheopis 4:1, more than 81% of the fleas from both Suncus and R. exulans were X. cheopis, and nearly equal numbers of each were found on R. rattus. Nearly 90% of the B. bengalensis fleas and 2/3 of the R. norvegicus fleas were X. astia. This distribution is particularly striking because all five species of hosts share the same habitats and no seasonal differences in mammal populations have been observed. It may be significant that X. astia was most abundant on the two species that tend to burrow underground (R. norvegicus and and B. bengalensis). We suspect that the former is more frequently found outdoors than indoors, and since X. astia was originally a gerbil flea and occurs naturally in semi-arid habitats in its native home (Indian Subcontinent), the disproportionate percentage of X. astia on Bandicota may be a reflection of the host's living in a relatively dry habitat for prolonged periods. It is significant that frequently only X. cheopis was found on Suncus (75% of the collections) and on R. exulans (76%).

6) Table 7 presents the available data on the fleas that were tested for R. mooseri infection by means of the FA test. Unfortunately, identifications to species are not yet available for the Xenopsylla that were dissected. The rate of 19%, for Xenopsylla, surpasses what we have seen anywhere else for any species. The single infected C. felis is of interest since it is our first record of R. mooseri in this species anywhere, but only limited numbers have been sampled thus far.

R. mooseri has been isolated from C. felis from the precise site where human cases of murine typhus had occurred (Irons et al., 1944), and C. felis from opossum have been found naturally infected with this agent (Irons et al., 1946; Keaton et al., 1953). Traub et al. (*# 1978) cite other data implicating C. felis in the epidemiology of this rickettsiosis, including reports of successful acquisition of R. mooseri by feeding on infected hosts.

FLEA	NUMBER POSITIVE	NUMBER TESTED	% POSITIVE
Xenopsylla	43	221	19%
Ctenocephalides felis	1	18	5%

TABLE 7. Numbers of Xenopsylla and Ctenocephalides felis that were positive for Rickettsia mooseri by direct FA test, Rangoon, Burma (1977 - July 1978)

c. Other areas

1) Tests by IFA for R. mooseri infection in Rattus and Mus musculus in areas of Lebanon, Pakistan, Australia, Sarawak and Baltimore are treated in Table 8.

HOST	AREA	NUMBER POSITIVE	NUMBER TESTED	% POSITIVE
Rattus norvegicus	Lebanon: (4 Towns)	2	26	8%
Rattus rattus	Lebanon: (Tripoli)	0	2	-
Rattus norvegicus	Pakistan: Karachi	2	22	9%
Rattus rattus	Pakistan: Karachi	0	8	-
Rattus norvegicus	Australia: Brisbane	0	14	-
Rattus rattus	Australia: Brisbane	0	10	-
Mus musculus	Australia: Brisbane	0	24	-
Rattus rattus	Sarawak: Kuching (Shops)	19	39	49%
Rattus rattus	Sarawak: Kuching (Residential)	0	13	-
2 Rattus (Others) 1 Mus	Sarawak: Kuching (Residential)	0	3	-
Rattus norvegicus	Maryland: Baltimore (Zoo)	0	32	-

TABLE 8. Results of IFA tests with rats and Mus from various areas as indicated

2) The results reported for R. norvegicus in Lebanon (8%) and Karachi, Pakistan (9%) support our views about murine typhus being a widespread infection in commensal rats in port areas where X. cheopis exists, but the 49% in Rattus rattus in Kuching greatly exceeds that reported in areas ecologically similar, e.g., Malaya, where Smith (1962) reported 16% of the house rats had antibodies to R. mooseri (Traub et al., 1978). Impressive as the Kuching percentage is, it does not approach what we had observed in Rattus rattus in Addis Ababa (53%-86%). It would be worth determining whether the negative results in Brisbane represent poor sampling regarding numbers of rats and localities examined, since the largest known outbreaks of murine typhus occurred within a few miles distant five decades ago. Baltimore, too, is a classical focus of murine typhus, but the limited results to date also suggest the possibility of a marked decline in endemicity. We plan to study both of the last two areas in order to clarify the intriguing possibilities.

3) Data on dissections of ectoparasites from Karachi and Brisbane are presented in Table 9, whence it can be seen that there were no positive results in the 506 arthropods examined from these areas. While the numbers tested are all small, they were sufficient to have demonstrated R. mooseri if the tests had pertained to Xenopsylla and rat-lice from Ethiopia and Rangoon. These findings likewise indicate the need for further study in those areas.

	RATTUS NORVEGICUS	RATTUS RATTUS	TATERA	FUNAMBULUS	ISOODON	SUNCUS	TOTALS
	BRISBANE, AUSTRALIA						
XENOPSYLLA CHEOPIS	0/16						0/16
PYGIOPSYLLA HOPLIA		0/10			0/20		0/30
STEPHANOCIRCUS DASYURI		0/10			0/7		0/17
LICE	0/80						0/80
MESOSTIGMATID MITES	0/36						0/36
TICKS	0/10	0/10			0/10		0/30
	KARACHI, PAKISTAN						
XENOPSYLLA	0/100		0/27			0/20	0/147
LICE	0/110		0/10	0/10			0/130
MESOSTIGMATID MITES	0/20						0/20
TOTALS	0/372	0/30	0/37	0/10	0/37	0/20	0/506

TABLE 9. Results of direct FA tests for Rickettsia mooseri infection, using ectoparasites from small mammals from Brisbane, Australia and Karachi, Pakistan

4) Only human sera were available for testing from Nepal, and as shown in Table 10, 6% of the 79 samples examined were positive for epidemic typhus-group rickettsiae by the IFA test. From these data alone it is impossible to state whether the donors had an infection of murine typhus or epidemic typhus or even with some other related agent. More specific tests are required.

NUMBER INFECTED	NUMBER TESTED	% POSITIVE	MAXIMUM POSITIVE TITERS			
			1:40	1:80	1:1280	1:2560
5	79	6	2	1	1	1

TABLE 10. Results of testing human sera from Nepal for presence of antibodies to epidemic typhus-group rickettsiae by the Indirect Fluorescent Antibody Test

d. Studies on Experimental Infection

1) One of the cardinal questions about the epidemiology of an arthropod-borne disease is how the cycle is maintained in nature. Such information is, of course, vital before adequate control measures can be determined. Along with the precise vectors and means of transmission, this point is still somewhat a mystery regarding murine typhus. Since 1) fleas (X. cheopis and several others) with R. mooseri remain infected for life; 2) their life-span of several months is unaffected by the rickettsiae; and 3) commensal rats breed throughout the year and have a gestation period of 3-4 weeks, and it has been suggested that in this way fleas alone could perpetuate the agent in nature, as indicated by Dyer et al. (1932); Ito et al. (1975); and documented by Traub et al.,(*#1978). Inherent in such a cycle is the fleas' acquiring the infection by feeding on the rats, but it has generally been assumed that the rickettsemia lasts only about a week in the rat, and this means that during its life, each infected rat can supply only a limited number of fleas (or lice) with R. mooseri and that over a span of but a few days during the initial attack (Blanc & Baltazard, 1944; Traub et al.,*#1978). However, because dried flea feces can remain infective for years under certain conditions, Blanc & Baltazard (1944) referred to the feces of infected fleas as the "reservoir" of the infection. We have suggested (Traub et al.,*#1978; Traub et al.,*#in press) that the infected rat may suffer a recrudescence under certain yet unknown conditions and sustain an infective rickettsemia analogous to that seen in man with R. prowazeki in Brill-Zinsser disease. We are carrying out special studies in an attempt to get information along these lines and related points, viz., strain characteristics, the immune response, persistence of the rickettsiae, etc.

2) In research on characterization of the agent isolated from Ethiopian Rattus rattus, it has been found that the average titer of Rickettsia mooseri Seed B, AZ-332, was 6.07 x 10^8PFU/ml, using primary chick embryo cell cultures. The number of rickettsial bodies per ml was calculated as 92.48 x 10^8. Studies on rickettsemia showed that adult rats inoculated with 100 PFUs (0.1 ml intradermally) disclosed a short period of relatively low detectable rickettsemia from 8 days after inoculation to 14 days post-inoculation. Antibodies appeared within 10 days and reached a peak of 1280 serologic titer by IFA test within 6-7 weeks after inoculation. Rickettsiae were demonstrated in the brain and kidneys 2-3 and 4 weeks post-inoculation respectively. It thus appears that at least for a low level of rickettsiae

(which nevertheless is sufficient to produce antibodies and tissue infection) the rickettsemia is of short duration. These studies are being continued.

3. STUDIES ON OTHER RICKETTSIAL INFECTIONS

a. Tick-borne rickettsiosis

1) As previously indicated, contrary to the impression created by the dearth of reports in the literature, the spotted fever group of rickettsiae is widespread in Ethiopia, at least in rodents. Our data on this score are summarized in Table 11 insofar as concerns rodent blood tested by IFA, and four important points are immediately apparent: 1) Rattus presumably plays no role in the ecology of this infection in the areas tested; 2) tick-borne rickettsiosis occurs in all the areas adequately sampled (bearing in mind that Intoto is just 2 miles from Addis Ababa); 3) the infection rate may be surprisingly high; and 4) "wild" rodents that live in or enter domiciles may be naturally infected with tick typhus.

2) No infected Rattus were found whatever, either at Koka or in Addis Ababa, despite the large number tested. This probably represents the virtual restriction to the indoors by the rats in both areas (presumably due to the cold temperatures at Addis and the aridity at Koka) and which greatly limits the chances of the rats coming in contact with ticks. It will be recalled that we have not found ticks on the Rattus examined at Addis, and they were scarce on rats in the huts at Koka. The fact that some native murines trapped indoors were infected with rickettsiae below (as also mentioned in paragraph 3) below and depicted in Table 12) is apparently because the huts in these areas either have bare earth floors or are so poorly constructed that wild rodents can enter and leave at will.

3) A total of 26% of 99 Arvicanthis in the acacia grove area of Koka were naturally infected with these rickettsiae, but the 49 Arvicanthis tested in the suburbs of Addis were apparently negative. This anomaly is interesting and may be important regarding the ecology of tick-borne rickettsiosis. As previously indicated, a notable proportion of the ticks from these rodents at Koka, including species found positive for these rickettsiae by the FA test, feed on cattle during the adult stage of their life cycle. The acacia groves of Koka are daily visited by herds of cattle and goats, and this no doubt helps account for the relatively large tick population there on rodents. However, there are cattle and horses in the Addis suburbs as well, e.g., at the Makanissa barn, but ticks were very scarce on rodents in the environs. Cattle ticks, however, abound. It might be thought that since the fields near Addis are under cultivation and are plowed, while acacia groves are unplowed, the difference in the tick population (and the incidence of naturally infected ticks and rodents) is due to the annual modifications of the environment. This may very well be a critical factor, but there are sections near Addis which are not disturbed by agriculture, and here the tick population has been low as well (although the sampling has been rather limited). The marked difference in temperature between the Rift Valley, at 1640 m. and Addis, at 2300-2500 m., does not seem to be the critical factor concerning tick typhus, because we have demonstrated that 22% of 9 Arvicanthis from Mt. Intoto harbored these rickettsiae, and these were from 3500 m., where it is much colder than in nearby Addis. Further, we have shown that in Pakistan tick-borne rickettsiosis was endemic in the high mountains in alpine terrain, i.e., ecologically analogous to conditions on Mt. Intoto, and even at higher and more rigorous areas in the Himalayas (Robertson et al.,# 1970; Robertson & Wisseman, 1972). (Ticks from cattle from Addus and Koka were tested in limited number, as

HOSTS	ADDIS ABABA		KOKA-RIFT VALLEY		INTOTO		LEMI	MENAGESHA	ANKOBER	TOTALS
	BUILDINGS	SUBURBAN FIELDS	TOWN	FIELD AREA	HOUSES	OUTDOORS				
RATTUS RATTUS	0/181	X	0/98	0/8 (7 in mos)	0/48		X	X	X	0/335
ARVICANTHIS SP.	X	0/49	X	26/99 26%		2/9 22%	0/10	@	0/17	28/184 15%
DESMOMYS	X	X	X	X	2/13 15%	0/6	0/5*	0/3	[illegible]	2/27 7%
LOPHUROMYS	X	X	X	X			0/2*	X	0/8*	0/10
MASTOMYS NATALENSIS	X	@	@	5/43 12%			0/15	0/14	X	5/72 7%
MUS MUSCULUS	0/6				0/2					0/8
MUS (LEGGADA)	X	0/4*	X	X			0/1*	@	@	0/5
OTOMYS TYPUS	X	X	X	X			X	X	0/8*	0/8
PRAOMYS ALBIPES	X	X	X	X	4/118 3%		1/28** 4%	2/19** 11%	X	7/165 4%
STEPHOCEPHALEMYS SP.	X	X	X	X			X	X	0/1*	0/1
TATERA ROBUSTA	X	@	X	0/2			X	X	X	0/2
TOTALS	0/187	0/53	0/98	31/152 20%	6/181 3%	2/15 13%	1/61 1.6%	2/36 6%	0/34	42/817 5%

TABLE 11. RESULTS OF INDIRECT FLUORESCENT ANTIBODY TESTS FOR INFECTIONS OF THE SPOTTED FEVER GROUP, USING BLOOD COLLECTED ON FILTER PAPER, FROM SPECIFIED RODENTS IN PARTS OF ETHIOPIA (1975-1976)

Numerator = Number positive. Denominator = Number tested. X = Rodent not collected and may be absent. @ = Rodent present but not tested. * = Tested with fluorescein-conjugated antiserum to *Arvicanthis* globulin. ** = Ditto re *Mastomys*.

reported last year, and were negative. Since federal regulations prohibit the importation of sera from cattle into the U.S., we have not been able to obtain data on the infection rate in cattle.)

4) There does not seem to have been any previous report of theraphions with natural infection with rickettsiae of the spotted fever group being in such intimate contact with man as we have noted in Ethiopia, where the local people in rural areas frequently complain that "rats" bite them, or lick their hair, at night in bed. These "rats" are native murines, Praomys, Desmomys, Arvicanthis and Mastomys, and they commonly are found as commensal pests in localities where Rattus does not seem to be found, as at Lemi, Menagesha and the uppermost village on Mt. Intoto (e.g., Intoto Maryam). Some coexist with Rattus at Intoto Kedani Mehret and in huts in the fields at Koka, but in both of these places there is significant ecological difference - the Rattus are almost invariably trapped on the ceiling-beams and the tops of cupboards and cabinets, while the native murines are on the ground. The difference in habitat and host is also reflected by the flea-fauna to a notable degree. L. segnis has been essentially restricted to Rattus and Mus musculus and the indoors, but Ctenophthalmus has been found only on Arvicanthis. Desmomys and the other indigenous murines. Leptopsylla aethiopica has been collected only on native species of Mus (Leggada).

5) Data on spotted fever-group rickettsial infection in "indoor" versus "outdoor" murine hosts are shown in Table 12, and it is clear that the mammals trapped indoors may, with the notable exception of Rattus, have significant evidence of such infection. Thus, not only have all four genera of native murines been thusly incriminated, but as many as 30% of the 26 Arvicanthis collected in buildings have been implicated. Such infected domiciliary mice or rats have been found in all of the foci studied save Addis, where the introduced commensal Rattus and Mus musculus have been the only denizens noted in buildings.

6) Inasmuch as these native murines, often infected with these rickettsiae, have such ready access to homes and buildings and are so prone to behave as commensals, it is expected that they will seed such edifices and environs with engorged larval and nymphal ticks that may also be infected (by transmission or by acquisition from a rickettsemic host). The next stage of tick may attach to, and infect, man, and it should be borne in mind that in Africa and Asia some rodent ticks feed readily on human beings although such is not the case in the U.S. Further, since the local people at times corral their cattle near or next to their homes, and they have dogs and cats, infected adult ticks are also likely to be on the premises. Last year we reported that 4 mites from a pool of 10 from Desmomys (out of a total of 30 mites from 3 Desmomys) at Intoto were naturally infected with spotted fever-group rickettsiae. Such mesostigmatic mites often bite man, although nothing is known about the habits of these African species. For all of these reasons, it is believed that tick typhus is a common infection of various mammals, and probably man as well, but adequate data are lacking.

b. Chigger-borne rickettsiosis

1) It is unfortunate that we could not follow up our observation that the vector-group of chiggers (the subgenus Leptotrombidium) occurs in the mountains of Ethiopia even though they had never been reported in Africa, for there has been no definitive evidence that scrub typhus is endemic on that continent and serological evidence to the contrary cannot be properly evaluated (Traub & Wisseman,# 1974). We

	RATTUS RATTUS	ARVICANTHIS	MASTOMYS NALALENSIS	PRAOMYS ALBIPES	DESMOMYS	SUBTOTALS
1. ADDIS ABABA Buildings	0/181	Not Found	Not Found	Not Found	Not Found	0/181
Outdoors	Not Found	0/49	Not Tested	Not Found	Not Found	0/49
2. KOKA FIELDS Huts	0/7	8/26 30%	2/18 11%	Not Found	Not Found	10/51 20%
Outdoors	0/1	18/73 25%	3/25 12%	Not Found	Not Found	21/99 21%
3. KOKA TOWN Buildings	0/98	Not Found	Not Tested	Not Found	Not Found	0/98
4. LEMI Town Bldgs.	Not Found	Not Found	0/15	1/24 4%	0/5	1/44 2%
Fields	Not Found	0/10	Not Tested	0/4	Not Done	0/14
5. MENAGESHA Town Bldgs.	Not Found	Not Found	0/14	2/12 17%	0/1	2/27 7%
Fields	Not Found	Not Tested	Not Tested	0/7	0/2	0/9
6. INTOTO Buildings	0/48	Not Found	Not Found	4/118 3%	2/13 15%	6/179 3%
Outdoors	Not Found	2/9 22%	Not Found	Not Tested	0/6	2/15 13%
SUBTOTALS Indoors	0/334	8/26 30%	2/47 4%	7/154 4.5%	2/19 10%	19/580 3%
Outdoors	0/1	20/141 14%	3/25 12%	0/11	0/8	23/186 12%
TOTALS	0/335	28/167 17%	5/72 7%	7/165 4%	2/27 7%	42/766 5%

TABLE 12. Natural Infection with rickettsiae of the spotted fever group occurring in "wild" murines trapped in houses in Ethiopia as compared with 1) outdoor individuals and 2) commensal Rattus, as shown by IFA test (1976-1977).

hope that it will be possible to resume field-work in the mountains of the Horn or in East Africa, because chigger-borne rickettsiosis has been found to be endemic wherever such Leptotrombidium have been collected (if adequately tested).

2) Rangoon is unusual in south Asia in that the vector-group of Leptotrombidium chiggers is apparently absent or exceedingly rare in the area, the abundance of grassy habitats and outdoor Rattus notwithstanding, as shown by our joint study with the Rodent Control Demonstration Unit of the W.H.O. L. deliense does

occur within about 10 miles of Rangoon, as near the airdrome, but it is uncommon and apparently seasonal there. During World War II there were no cases of scrub typhus reported for Rangoon, but one or two were noted in the precise area (Audy & Harrison, 1951), and we have since demonstrated L. deliense there. In contrast, the Arakan section, Middle Burma and Upper Burma are notorious for hyperendemic foci and for a fauna of Leptotrombidium rich in number of species and individuals (Traub & Wisseman,# 1974; Traub,# 1949).

4. PUBLICATIONS BY THESE INVESTIGATORS

a. Our extensive, critical review of the ecology of murine typhus has been published in the Tropical Diseases Bulletin (Traub et al.,# 1978). Included are some original observations based upon our Ethiopian studies. A summary of our views on the subject, with new emphasis on how the probability of aerosol transmission via infective flea-feces means that even fleas and rat-lice that do not bite man may perhaps be important sources to man and rat, is in press (Traub et al.,# in press). The rats that were collected during the studies on murine typhus provided us with an opportunity to obtain data on the incidence of the helminth parasite Capillaria hepatica. The results have been published (Farhang-Azad & Schlitter,# 1978) and recall the findings with murine typhus in that out of 28 species of small mammals examined, only Rattus and Praomys, both commensals, were implicated. Thus, 6% of the 308 Rattus examined and one of 212 Praomys were infected, in contrast to negative results in 161 Arvicanthis, etc. Another parallel was that the incidence of infection in Rattus from Addis Ababa was 8 times higher than that from Koka.

b. There have been some recent publications prepared by the Responsible Investigator and members of this Department that are directly pertinent to the work being done under this Contract but which represent sponsorship by non-Navy sources. They are mentioned for documentation, for purposes of completeness regarding current state of the art, and so that the bibliography cited in this report is up to date and suitable for reference. As in the case of other relevant work done under other auspices by our staff, the items marked with a #, and are as follows: The characteristics of R. mooseri infection in guinea pigs have been noted and described (Murphy, Wisseman & Fiset,# 1978) and two papers by those authors are in press, likewise in the journal, "Infection and Immunity." One deals with the adaptive transfer of immunity to R. mooseri, and the second with the characteristics of intradermal R. mooseri infection in normal and immune guinea pigs. It has been shown that the organization of the cell envelope of R. tsutsugamushi differs substantially from that of the other species (Silverman & Wisseman,# 1978). A slime layer in R. prowazeki and R. rickettsii has been noted for the first time (Silverman et al.,# in press in "Infection and Immunity").

5. SUMMARY OF PROGRESS REPORT

a. The material collected in the field in Ethiopia and Burma, and that received from collaborating agencies, has once again resulted in substantial progress during the Contract-year.

b. The Ecology of Murine Typhus

1) The data acquired and analyzed this year support and extend the observations and contentions previously reported. Thus, 9% of the 1392 fleas from Rattus in Ethiopia that were dissected and examined by the direct fluorescent antibody

(FA) test were positive for Rickettsia mooseri. All of the 367 fleas from other hosts were uniformly negative by these criteria, and 245 of these fleas were from Praomys and 122 from other murine hosts or Crocidura shrews, etc. Many of the "negative" fleas were from native murine species trapped indoors, e.g., Praomys, Desmomys and Arvicanthis. More and more, the data indicate that Rattus is cardinal to the ecology of this rickettsiosis in Ethiopia, e.g., 62% of the 190 Rattus examined at Addis harbored R. mooseri, as shown by the indirect fluorescent antibody (IFA) test, and of the 512 other hosts, only 4 were positive, viz., 1 of 9 Mus musculus and 3 of 355 (0.8%) Praomys, and these murines were indoor commensals where Rattus was also present. It is stressed that in Ethiopia all but one or two of the Rattus were collected within buildings.

2) The R. mooseri infection rate in Leptopsylla segnis fleas was significantly higher than that for Xenopsylla cheopis, the putative vector or in X. bantorum (hitherto not incriminated in murine typhus) in areas where all three coexisted in Ethiopia. Thus, in Addis, the L. segnis rate was 15% versus 3% and 7% for the others. L. segnis was also far more prevalent than Xenopsylla in Addis, but was not found at Koka, in the Rift Valley, where there was a low rate of natural infection in town Rattus.

3) It is apparent that neither Rattus, nor X. cheopis by themselves can account for the prevalence of R. mooseri in rats, especially when it is recalled that this flea abounds on Arvicanthis in the acacia groves of the Rift Valley in the absence of known infection.

4) A total of 6% of the Rattus lice from Addis were found positive for R. mooseri, but no rickettsiae were found in mesostigmatid mites.

5) Hyperendemic foci were found in Addis Ababa, where the great majority of rats and their fleas and lice were found to be simultaneously positive for R. mooseri.

6) Analogous results were observed in Rangoon where, however, L. segnis does not occur. Six species of small mammals (theraphions) - five murines and one shrew - are present there in buildings and all five of those adequately sampled were found naturally infected with R. mooseri. The rate varied from 7% in Mus musculus to 28% in Rattus rattus and 38% in Bandicota bengalensis.

7) Among the ectoparasites in Rangoon, only fleas (18%) and rat-lice (7%) have been found (by FA) naturally infected with R. mooseri. Except for a rare Ctenocephalides felis (cat-flea) or Echidnophaga gallinacea (stick-tight flea), only Xenopsylla cheopis and X. astia were found on these theraphions. Both species of Xenopsylla were found on all five common hosts, but X. astia was far more numerous (66% and 89% of the totals) on R. norvegicus and Bandicota bengalensis than on the others, while more than 80% of the fleas on Rattus exulans and the shrew Bandicota bengalensis were X. cheopis.

8) One infected C. felis was noted among 18 tested (5%) while 43 of 221 (19%) Xenopsylla harbored R. mooseri in Rangoon.

9) Tests by IFA of blood from limited samples of Rattus disclosed R. mooseri infection in 8% of the R. norvegicus tested from Lebanon; 9% of the R. norvegicus from Karachi, Pakistan, and 49% of the R. rattus from shops in Kuching, Sarawak. Interestingly, none of the 16 rats from residential areas in Kuching were infected. In IFA tests on 79 human sera from Nepal, 6% were positive.

10) In studies on experimental R. mooseri infection in laboratory rats, it was observed that the rickettsemia at the dosage employed is of very short duration (6 days). This finding fits in with the general impression in the literature, and it is stressed that the dosage we used produced an antibody response, and it was possible to recover rickettsiae from rat tissues 4 weeks after inoculation.

c. Tick Typhus

1) Infection with the spotted fever-group of rickettsiae was shown to be widespread in Ethiopian rodents, including "wild" murines that entered domiciles, and the infection rate in Arvicanthis out in the fields at Koka was as high as 25% and 30% for those caught inside huts. Significantly, no Rattus were observed to be infected with such rickettsiae. On a mountain (Intoto) two miles from Addis Ababa, 15% of the 13 Desmomys trapped in huts were found positive for rickettsiae of the spotted fever-group, and infected Arvicanthis were collected outdoors as high as 3500 m. elevation, under alpine conditions.

d. Other Points

1) Chigger-borne Rickettsiosis. Despite the abundance of outdoor rats and ostensibly suitable habitats, members of the L. deliense-complex, the group that serves as vectors of scrub typhus, are absent or exceedingly rare in Rangoon. This is a highly unusual or unique condition for a town in S.E. Asia and is worth documenting further. L. deliense has been found near the Airport for Rangoon, but is extremely uncommon and seasonal.

2) Our extensive and critical review of the ecology of murine typhus has been published in the Tropical Diseases Bulletin (Traub et al.,*# 1978), and another paper by those authors and on that subject is in press. An article by Farhang-Azad & Schlitter,*# 1978) on Capillaria infection, based upon studies of this helminthic parasite in Ethiopian rats executed under this Contract, has been published.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The observations reported confirm and extend the material previously reported. Thus, in Ethiopia and Burma, as in other areas we are studying, murine typhus is intimately associated with introduced commensal rodents (Rattus, Mus musculus, etc.) and shrews (Suncus) and their ectoparasites, indoors. In Ethiopia, native rodents, like Praomys and Mastomys, that may act like commensals do not seem to play a role in the ecology of this rickettsiosis in the absence of concurrent infestation with Rattus, even though they may be common in domiciles and parasitized by Xenopsylla cheopis, the presumed vector. If Rattus coexist indoors with

20. ABSTRACT (continued)

Praomys, then the latter (and probably other native murines as well) may become secondarily infected on a limited scale. In Rangoon, 5 species of small mammals are peridomestic and all have been frequently found naturally infected with Rickettsia mooseri, the etiological agent. Among the naturally infected fleas found in this study are X. bantorum, Leptopsylla segnis and Ctenocephalides felis. Rat-lice in Ethiopia and Rangoon have also been found to harbor R. mooseri. Rats from shops in Kuching, Sarawak, were demonstrated to have a high rate of natural infection with this rickettsiosis.

Infection with the spotted fever-group of rickettsiae was shown to be widespread in Ethiopian rodents, including some "wild" rodents that entered domiciles.