A Review

Murine Typhus Investigations in Southwestern Georgia

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EFFORTS to control murine typhus fever in the southeastern United States, although overshadowed by accomplishments in the control of malaria, have achieved results which are almost as spectacular. An outstanding reduction of murine typhus transmission was accomplished within 25 years after the role of the rat and rat flea as host and vector of murine typhus was first suggested by Maxcy in 1926 (*1*) on the basis of epidemiological studies in Alabama and Georgia and validated in 1931 by Dyer, Rumreich, and Badger (*2*), who isolated the pathogen from fleas collected from wild rats.

The introduction of DDT, an insecticide with prolonged residual toxicity, into typhus control programs in 1945 and of anticoagulant rat poison in 1947 provided the tools with which the control of murine typhus was finally accomplished (fig. 1).

Incidence of the disease always has been greatest in the southeastern section of the country (fig. 2). Reported cases from 10 of the southeastern States rose from 1,799 in 1940 to 5,292 in 1944. Studies by Hill and co-workers (*3,4*) indicated that probably at least two-thirds of the cases were not reported at that time, although by 1953 Quinby and Schubert (*5*) indicated that the trend may have been reversed, and the disease was being over-reported.

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In Georgia, the number of reported cases of murine typhus rose from 57 in 1929 to 1,092 in 1937. Incidence of the disease was particularly high in the southern part of the State. By 1937 the disease had reached such proportions that a control program was initiated by the Georgia Department of Public Health (*6*). This program entailed elimination of harborage and food for rats and extermination of rats by trapping, poisoning, and rat-proofing of buildings. While these early programs were effective in localized areas, the total number of cases reported in the State rose to 1,135 in 1939, and 1,111 cases were reported in 1945 (fig. 3).

Bowdoin and Boston (*7*) stated that from 1932 to 1939 the greatest problems in the control of murine typhus in Georgia occurred in towns and villages and were associated chiefly with the business areas, particularly grocery stores, feed stores, and meat markets. However, beginning in 1945, shortly after Davis (*8*) demonstrated that DDT would control rat fleas, control programs using this compound so successfully disposed of these problems that by 1948 nearly 80 percent of 142 cases investigated in Georgia occurred in rural areas (*9*).

With the advent of DDT dusting, it was foreseen that the precise effect could be measured accurately only by investigating the numerous factors which affect transmission of murine typhus. Accordingly, the Communicable Disease Center of the Public Health Service initiated studies on the control of the disease in support of State programs. The studies, conducted in several counties of southwestern Georgia, extended over a 12-year period from 1945 to 1957.

This report summarizes the information obtained from the investigations, compares the results from the various studies, and records conclusions concerning the control and possible eradication of murine typhus fever.

Typhus Control Program

The area selected for studying the effectiveness of DDT dusting comprised portions of Brooks, Decatur, Thomas, and Grady Counties in southwestern Georgia (fig. 4). Decatur County operations were discontinued before completion of the project. In Brooks and Thomas Counties, the control program was confined to DDT dusting of domestic rat runways, burrows, and other rat habitats. Grady County was used as an untreated check area. Control operations, consisting chiefly of five applications of 10 percent DDT dust, extended from April 1, 1946, through September 30, 1947 (*4*).

The incidence rates per 100,000 population for human murine typhus, during the 18 months before dusting operations began, were 174 for Brooks County, 180 for Thomas County, and 232 for Grady County. During the first 18 months of the operational program, these rates were reduced to 14.7 for Brooks County and 31.5 for Thomas County, but remained rather constant at 236 in untreated Grady County (*4*). Data on annual incidence is given in table 1.

A similar reduction of the disease in commensal rats was shown by complement fixation tests on serums from domestic rats collected throughout the study (table 1). Tests on small samples of *Rattus rattus* collected prior to April 1946 revealed infection rates of 50, 63, and 46 percent in rats collected in Brooks, Thomas, and Grady Counties, respectively. Collections of this same species between May 1947 and April 1948 gave positive results on 3.4 percent of specimens from Brooks County, 7.4 percent from Thomas County, and 35 percent from untreated Grady County (table 1).

The incidence of murine typhus in *Rattus*

Figure 1. Annual total of reported murine typhus fever cases in the United States, 1932–57

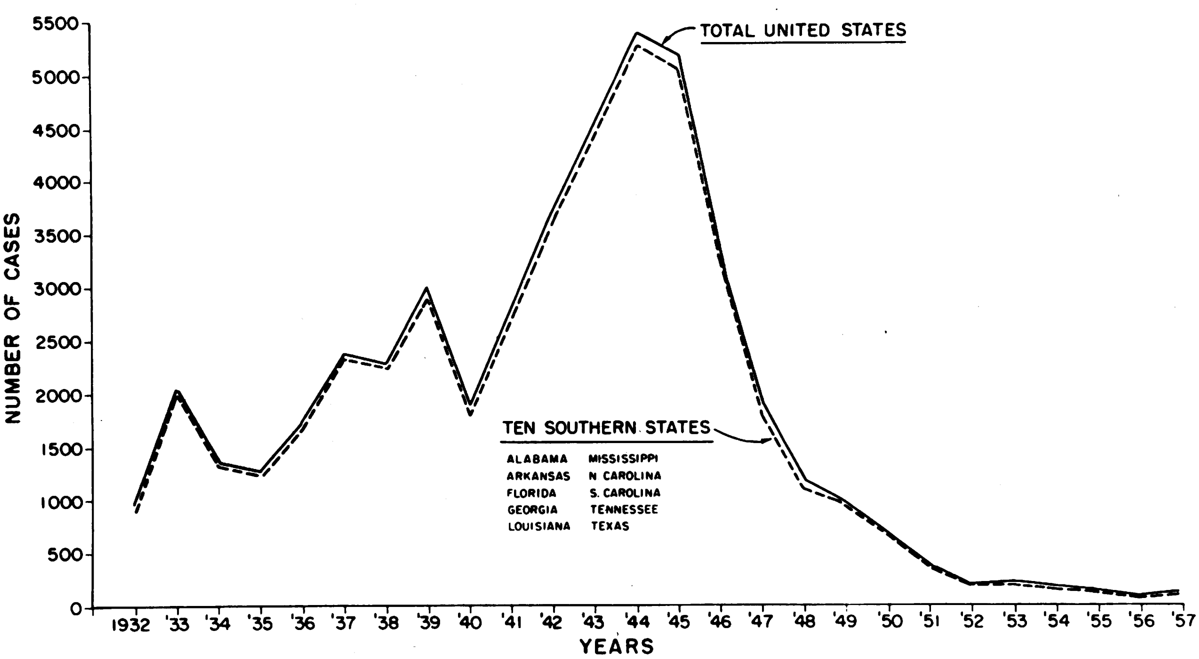
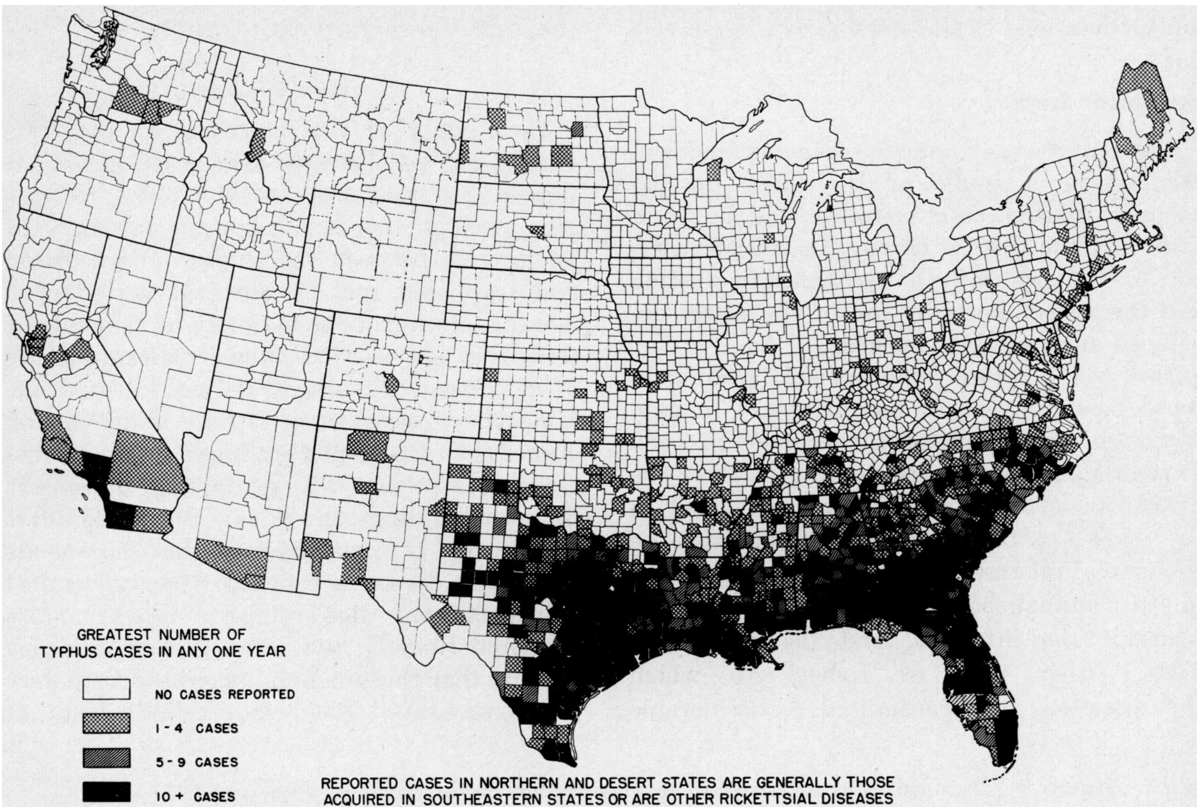


Figure 2. Reported cases of endemic typhus in the United States, 1941–47



norvegicus prior to dusting was not measured, since relatively few rats in this species occurred in these counties at that time. However, in Thomas County incidence in this species was reduced from 28 percent in May 1946 to 6 percent in April 1948. In Grady County, incidence in these rodents ranged between 37 and 38 percent throughout this period.

This first study showed that good control was obtained for the oriental rat flea, *Xenopsylla cheopis* (table 1), and the mouse flea, *Leptopsylla segnis*. Control of the sticktight flea, *Echidnophaga gallinacea*, was erratic and little or no control of rat mites and lice could be noted. The study demonstrated decisively that murine typhus fever could be controlled with DDT.

The duration of control was studied between 1948 and 1950 (*10*, *11*). Morbidity rates for human murine typhus continued to drop in the treated areas through 1950. In Thomas County, 69 cases occurred in 1945 in a population of approximately 34,000 people. This figure was reduced to seven cases in 1947 and to two cases in 1949. Human murine typhus was not found in Thomas County through September 1950. In 1945, Brooks County had 35 cases in a population of approximately 16,000. In 1947 there were no cases, but two cases occurred in each of the years 1948, 1949, and 1950. Grady County, with nearly 17,000 population, experienced 46 cases in 1945, 28 cases in 1949, and 19 cases during the first 9 months of 1950.

Commensal rats collected during July and August of each year between 1948 and 1950 showed a constant infection rate of approximately 40 percent in Grady County. In Brooks and Thomas Counties, a consistent rate of approximately 10 percent was indicated. During this same period, the number of rats infested with the principal vector, *X. cheopis*, remained constant in Grady County at approximately 60 percent. In the dusted areas, infestation rates rose from an average low of about 4 percent in 1947 to about 30 percent in 1950.

Thus, during the 3 years following the typhus control operations, human incidence continued to drop, incidence in rats remained constant, and populations of the chief vectors increased.

Ecological Studies

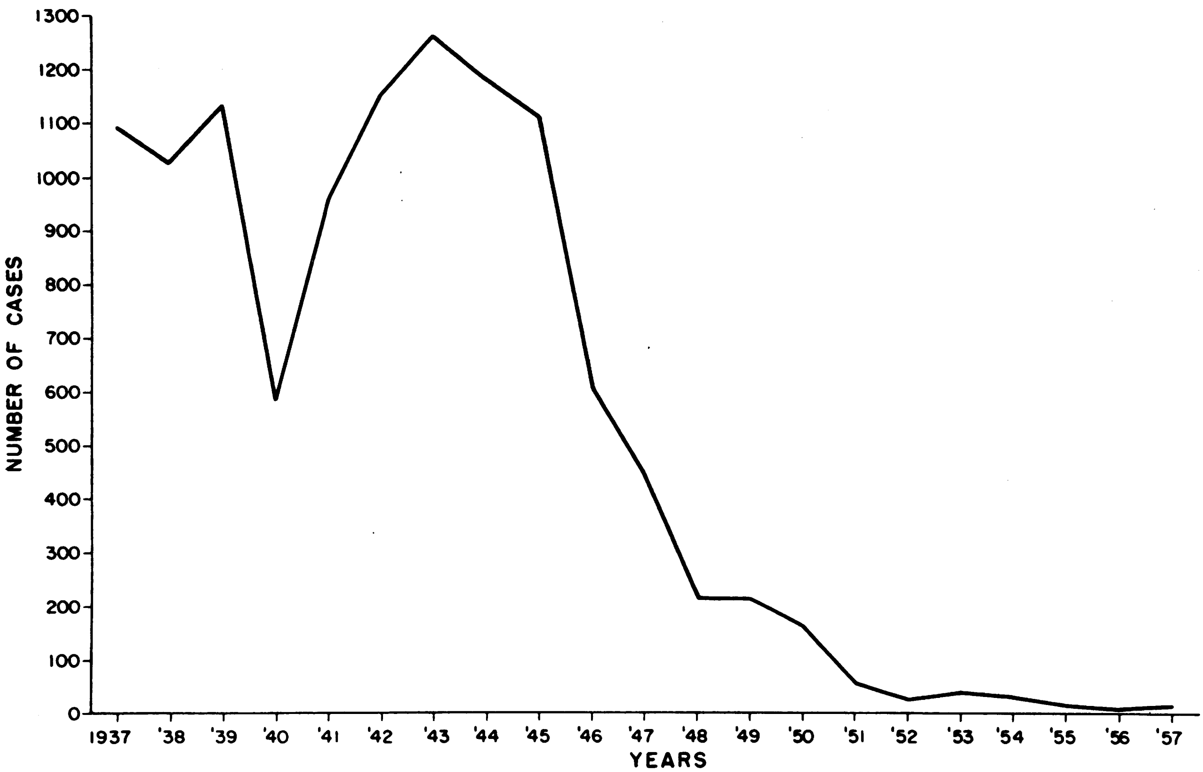
The reduction of murine typhus in commensal rats as a result of the DDT dusting program led to speculation concerning the eradication of the disease through a concerted effort to eliminate both the vector flea by dusting and the rodent hosts by use of the newly developed anticoagulant poisons.

However, before appropriate techniques could be developed, it was necessary to gain thorough knowledge of the ecology of each group of organisms participating in the cycle of murine typhus transmission. Involved in the cycle are the pathogenic *Rickettsia*, the commensal rat reservoir, the possible reservoirs in other animal species, the ectoparasites which transmit the infection, and the susceptible hosts, either man or rodent, to which the infections are transmitted. Considerable information concerning the ecology of these organisms was obtained during the course of the studies in southwestern Georgia.

Commensal Rats

In a study of the bionomics of roof rats Ecke (*12*) demonstrated a decreasing roof rat population from 1946 to 1951. The decrease was attributed to an increased mortality of young rats between the stages of parturition and trappable age. A survival period of 6 months or less for the majority of roof rats of trappable age was indicated by disappearance of 80 percent of marked rats within that time. Males disappeared more rapidly than females. Fewer than 1 percent were found to roam a distance greater than 500 yards, and movements between buildings more than 100 yards apart were rare. It was suggested that movements of greater distances resulted from mechanical transportation. Roof rats on premises that also harbored Norway rats had a greater tendency to move than those on premises where there were no Norway rats. Field evidence indicated that

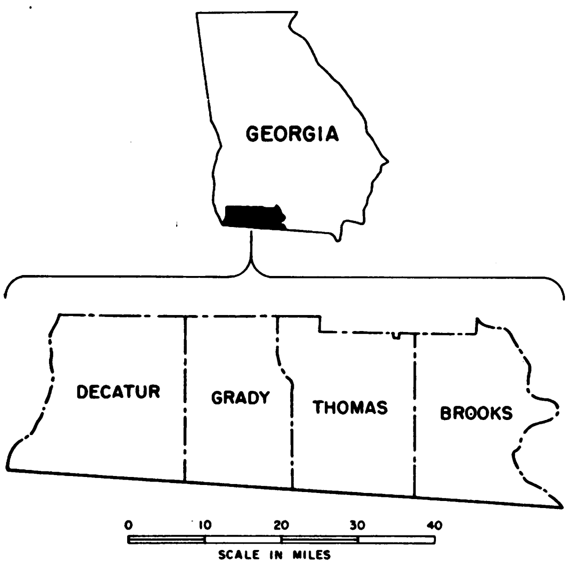
Figure 3. Annual total of reported murine typhus fever cases in Georgia, 1937–57



very few, if any, feral roof rats occur in southwestern Georgia.

The decline in commensal rat populations continued through 1956 (*13*). The incidence of infestations on farms in Thomas County dropped from 94 percent in 1946 to 35 percent in 1956. Studies indicated that although many ecological factors contributed to the decline, a series of drought years from 1949 through 1956 was apparently the most important factor. The scarcity of normal winter and spring rat foods, chiefly corn and peanuts, is believed to have affected the rat population adversely.

Figure 4. Location of typhus investigations in southwestern Georgia



In the three counties in which the typhus studies were being conducted, Ecke observed that between 1946 and 1951 Norway rats were constantly extending their range from north to south, invading roof rat territory (*14*). In 6 years the Norway rats over-ran about 1,000 square miles (fig. 5). The more aggressive Norway rats were able to exclude the roof rats from most of the infiltrated territory.

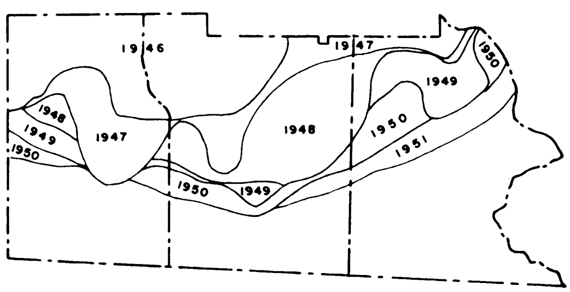
Melanism in the rat population of southwestern Georgia was reported by Smith (*15*). One hundred (19.1 percent) of the 523 Norway rats trapped alive in four counties of southwestern Georgia were black mutants. The high percentage of melanism indicates the probable inheritance of this character as a simple Mendelian recessive. Black mutants were more prevalent southward of the advancing front of the invasion of Norway rats than elsewhere in the area. The mutants, it is believed, were chased out of the more stable colonies of normal Norway rats into roof rat territory where competition is less. Keeler (*16*) found that the black rats were much less aggressive than the Norways of normal color. There was no significant difference in the incidence of melanism in the sexes of the Norway rats trapped (18 percent of males black, 20 percent of females). No difference in the prevalence of typhus antibodies was noted between the normal Norways and the black ones (7.3 percent and 7.0 percent, respectively).

The effect of DDT dusting on commensal rats was studied by Dent and associates (*17*). They showed that the distribution of 10 percent DDT dust in rat habitats resulted in pathological changes consistent with DDT poisoning

Table 1. Results of murine typhus control program in Brooks, Thomas, and Grady Counties in southwestern Georgia

Period	Brooks	Thomas	Grady
	Incidence of human murine typhus per 100,000 population		
1945	218	202	274
1946	72. 8	97	290
1947	0	19. 2	162
1948	10. 5	8. 5	141
1949	10. 5	5. 7	151
	Percent of *R. rattus* positive to complement fixation test		
April 1946	50	63	46
May 1946–April 1947	25	42	41
May 1947–April 1948	3. 4	7. 4	35
July and August 1948	. 5	8. 0	37
July and August 1949	4. 5	10	40
July and August 1950	9. 5	9. 5	45
	Percent of *R. rattus* infested with *X. cheopis*		
April 1946	20	40	45
May 1946–April 1947	13	30	60
May 1947–April 1948	1. 8	5. 6	41
July and August 1948	3. 5	19	58
July and August 1949	17	26	66
July and August 1950	25	31	74

Figure 5. Roof rat territory over-run by Norway rats, 1946–51



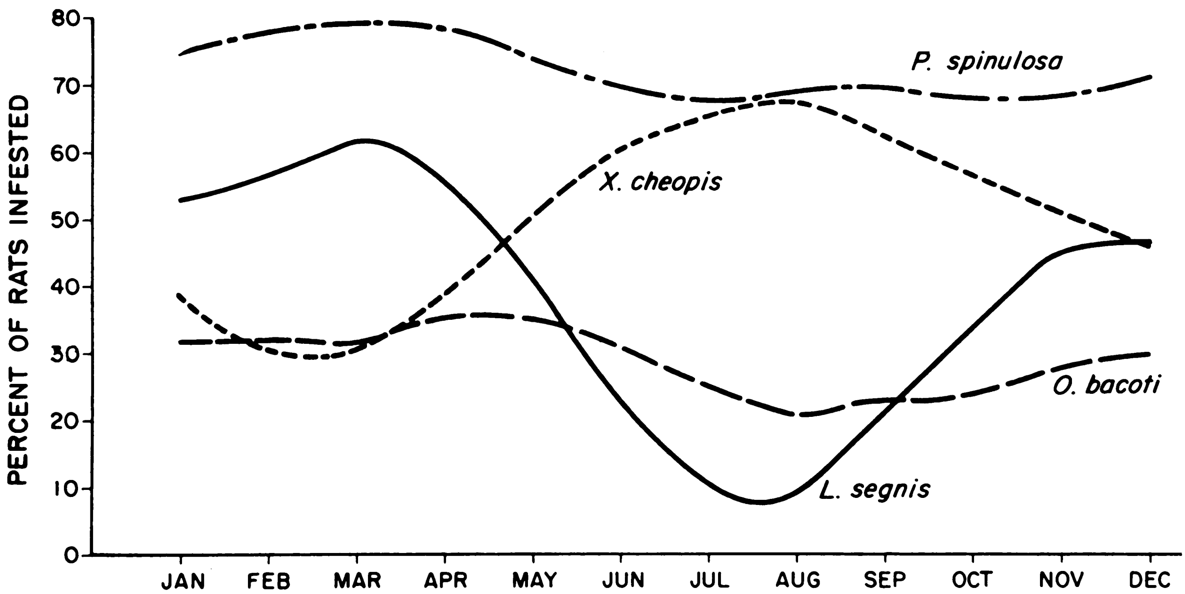
and in the accumulation of appreciable quantities of DDT and DDA in the livers and fat of exposed rats. In a treated colony of rats, 32.7 percent died within 7 weeks and 36.3 percent within 11 weeks, apparently from DDT poisoning. However, field observations indicated that such rates are in excess of those to be expected under natural conditions where rats can exercise greater freedom in avoiding unfavorable situations.

In a study of the ecology of commensal rats in relation to murine typhus, Morlan and associates (*18a*) observed that rats abandoned well-established, dusted runways in favor of new, undusted ones. They also suggested that fluctuations in rat populations on rural premises were more affected by the amount of food available than by changes in climatic conditions. From a study of captive colonies of rats, they concluded that odor trails of established runways may be an important guide to rats. Measurement of more than 3,500 specimens determined the average body length of immature roof rats to be 124.3 mm. and for adults 165.9 mm. Average body lengths of Norway rats were 140.5 mm. for young and 206.3 mm. for adults. Reproductive activity for both species of rats centered around one peak in March and a lesser peak in August. In both species reproductive capacity was proportional to body length. The average titer level of positive serums from Norway rats was considerably higher than that for serums from roof rats, but there was no consistent difference in prevalence of typhus antibodies in the two species.

Ectoparasites

The ectoparasites of commensal rats in relation to murine typhus were studied by Morlan and associates (*18b*). Between May 1946 and April 1949, more than 20,000 rats were trapped and examined for ectoparasites. *X. cheopis*, *L. segnis*, *Ornithonyssus* (*Bdellonyssus*) *bacoti*, and *Polyplax spinulosa* accounted for nearly 95 percent of the ectoparasites recovered. *P. spin-*

Figure 6. Seasonal abundance of the common ectoparasites of commensal rats as indicated by percent of rats infested (3-month moving average)



ulosa consistently infested a higher percentage of each species of rat than did any other ectoparasite. Rats which were positive to murine typhus complement fixation tests were more frequently infested with *X. cheopis* and *L. segnis* than negative rats. *X. cheopis* and *O. bacoti* infested young rats more frequently than adult rats. In an area without a murine typhus control program, *X. cheopis*-infested rats were found on between 80 and 90 percent of the premises from which rats were collected. Female *X. cheopis* and *L. segnis* predominated in samples of fleas taken. The proportions of female *X. cheopis* tended to increase in months with lower mean temperatures (60°–70° F.) and to decrease in months with higher mean temperatures (80°–90° F.). The seasonal prevalence of the most common ectoparasites of commensal rats is shown in figure 6.

Morlan (*19*) investigated the possibilities of adding either hydroxy-pentamethyl flavan or sulfur to DDT formulations in an effort to control effectively the tropical rat mite, *O. bacoti*, and the spined rat louse, *P. spinulosa*. Neither of these species was greatly affected by DDT dusting, but each of them transmitted murine typhus experimentally among laboratory animals (*20,21*).

A mixture of 8 percent DDT and 10 percent sulfur gave only slightly better control of the mite than DDT dust alone, and no appreciable reduction of the mite resulted from a mixture containing 8 percent DDT and 10 percent flavan. Neither of the mixtures significantly affected the spined rat louse.

Host relationships of arthropod ectoparasites were reported by Morlan (*22*). More than 506,000 ectoparasites were obtained from 32,320 mammals collected between October 1945 and April 1949. Twenty-eight host species yielded 7 species of *Mallophaga*, 7 species of *Anoplura*, 1 of *Hemiptera*, 3 of *Coleptera*, 5 of *Diptera*, 16 of *Siphonaptera*, and 66 species of *Acarina*. Small numbers of three additional host species were examined, but they were not infested. Forty-nine species of arthropods were collected from roof rats, 41 from Norway rats, 30 from cotton rats, 27 from opossums, 17 each from cottontail rabbits, gray squirrels, Florida skunks, and spotted skunks, 16 from cotton mice, 15 each from old-field mice, house mice, and raccoons, 12 from foxes, and 11 each from little brown bats, fox squirrels, and domestic cats. The remaining 12 host species were parasitized by 10 or fewer species of arthropods. The seasonal abundance of several species of cotton rat ectoparasites is also reported.

Epidemiology

A review by Stewart and Hines (*23*) of 452 cases of murine typhus occurring in southwestern Georgia from January 1945 to January 1953 showed a seasonal peak of rural cases during the summer but an even distribution of urban cases throughout the year. Incidence rates were about twice as high in rural as in urban areas and about eight times greater in the white persons than in Negroes. Age-specific incidence rates were low in children, rising to a peak during the fourth and fifth decades. The mean titer of the Weil-Felix test was high during the first week of a murine typhus illness and then rapidly declined, whereas the mean titer of the complement fixation test reached a peak during the second week and remained high over the next 50–60 weeks, after which it slowly declined. When patients were treated with aureomycin, there was a consistent lowering of the mean titers for the complement fixation test, but very little effect on the Weil-Felix titers was demonstrated.

Eradication Program

In July 1953, efforts were begun to eradicate murine typhus from the southeastern quarter of Grady County, an area of approximately 130 square miles. Dusting of rat runs plus the distribution of maintenance of rat poisons (fig. 7) at all premises infested with rats continued through May 1954 (*24*). Commensal rats were eliminated successfully from 309 (88 percent) of 349 rural premises during the 9-month eradication period.

	Number of premises
Total premises inspected	713
Infested and treated	349
Infested and treatment refused	3
Not infested	361
Cleared of rats	309
Eradication incomplete	40

Figure 7. Distribution of rat poison during murine typhus eradication program in southwestern Georgia

Twenty-five percent of these cleared premises became reinfested within 1 year (table 2), and about 30 percent were, or had been, reinfested at the end of 2 years. The third year's inspection revealed that 40 percent of the cleared premises had been reinfested at some time.

At the end of the operational phase of the eradication program, *X. cheopis* fleas were found on 9 percent of 70 rats collected at the 40 premises where rat eradication was not successful. Three months later, no *X. cheopis* was found on 34 rats collected at 16 premises where rats had been eliminated but where reinfestation had occurred. One year later, examinations of 162 animals collected from all farms (61) in the eradication area where trapping appeared to be productive disclosed no *X. cheopis*. At the end of 2 years, 142 rats were trapped from 42 premises where recent rat signs existed. Twelve rats (8.5 percent) had *X. cheopis* infestations. After 3 years 4.1 percent of 148 rats collected were infested with *X. cheopis*.

Positive complement fixation tests were obtained on 3 of 70 rats collected at the end of the operational phase of the eradication program from premises where rats were not eradicated. This indicated an incidence of slightly more than 4 percent in an area where murine typhus incidence in rats had averaged above 40 percent during the previous 9 years. Three of 34 rats collected from cleared but reinfested premises 3 months after eradication gave positive complement fixation tests. However, since these were adult rats it is believed they became in-

Table 2. Commensal rat infestations at farms 1, 2, and 3 years after the end of experimental typhus eradication measures in Grady County, Ga.

Infestation status	Number of years after treatment		
	1 (1955)	2 (1956)	3 (1957)
Number of premises inspected	532	532	493
Percent of premises cleared of rats by May 1954:			
Remained uninfested	70. 6	67. 0	58. 3
Infested at time of annual inspection	25. 4	17. 2	29. 9
Became infested, but clear at time of annual inspection	4. 0	15. 8	11. 8
Percent of premises uninfested during operational programs:			
Remained infested	91. 5	89. 4	85. 5
Infested at time of annual inspection	6. 7	3. 5	6. 7
Became infested, but clear at time of inspection	1. 8	7. 1	7. 8
Percent of premises not cleared of rats by May 1954:			
Remained infested	44. 8	24. 1	21. 4
Uninfested at time of annual inspection	55. 2	72. 4	46. 4
Became uninfested, but reinfested at time of annual inspection	. 0	3. 5	32. 2

fested before the eradication program was completed.

Of 124 rats collected from 78 premises 1 year after eradication only 1 rat gave a positive complement fixation test. This rat was taken at the extreme periphery of the area and probably had migrated from an untreated area. Tests on serums from 138 rats collected 2 years after eradication measures ceased indicated previous typhus infections in 4 rats (2.9 percent) collected from 2 farms. One farm was on the border of the eradication area, while the other was well within. Neither had previously harbored typhus-infected rats. Three years after eradication, complement fixation tests of serums from 148 rats trapped at 66 premises were negative.

Effectiveness of Control and Eradication

Results of the DDT dusting program and the eradication program are not directly comparable for many reasons. The studies were not conducted concurrently, and environmental factors which affect rodent and ectoparasite populations were not consistent throughout the periods covered by the two studies. Both programs were highly effective, and the advantages of one over the other are speculative. In the dusting program, maximum effectiveness appears to have been obtained in approximately 1 year during which four dusting cycles were completed. Each cycle required about 3 months to complete, but because of the residual effectiveness of DDT it is doubtful that more frequent dusting would have produced better results. The operational aspects of the eradication program were completed in 9 months, but because of the climatic variations this difference of 3 months cannot be considered significant. It is probable, however, that a larger working force may have completed the eradication program in a shorter time. Since rat runs were dusted on both programs, the choice between the two must be made on the basis of the advantages of removing rats. At first glance, and certainly for immediate control, rat poisoning would appear desirable.

A program which produces such obvious effects as the removal of rats is readily accepted, although this acceptance usually takes the form of verbal encouragement rather than assistance. The majority of property owners cooperated to the extent of letting their premises be treated.

The poisoning of rats increases the activity of their ectoparasites and consequently increases the percentage which would contact a well-distributed residual insecticide. Also the reduction or elimination of rats provides far less opportunity for the multiplication of the small residuum of ectoparasites. However, from the viewpoint of controlling arthropod-borne diseases, the increased ectoparasite activity which accompanies rat poisoning may also increase the possibility that people will be bitten by infected specimens.

The dusting program effectively held ectoparasite populations at a low level for approximately 1 year after operations had stopped (table 3). Dusting once a year at the optimum time may maintain the ectoparasite populations at a low level in a rather stable commensal rat population. When both rats and ectoparasites

Table 3. Comparison of results of control and eradication programs

Program status	Dusting program		Eradication program	
	Percent of rats positive to complement fixation test	Percent of rats infested with *X. cheopis*	Percent of rats positive to complement fixation test	Percent of rats infested with *X. cheopis*
Preoperations survey	50. 0	40. 0	40. 0	65. 0
Operations suspended	4. 0	12. 5	4. 3	9. 0
1 year postoperations	4. 0	4. 0	. 8	. 0
2 years postoperations	7. 0	20. 0	2. 9	8. 5
3 years postoperations	10. 0	30. 0	. 0	4. 1

are removed, unless constant surveillance is maintained, premises become reinfested with rats which reintroduce ectoparasites from beyond the periphery of the control area.

In the typhus eradication area of Grady County, premises freed of rats became reinfested at the rate of 25 percent during the first year, 30 percent in 2 years, and 40 percent in 3 years. These data indicate that commensal rat populations probably return to former levels at a slower rate than would the ectoparasite populations when rats are not removed. Neither the dusting program nor the eradication program completely eliminated vectors or reservoirs of murine typhus. Subsequent to the dusting program serologically positive rats were reduced to 4 percent of the population. But as a result of the eradication program, the amount of typhus in the rodent reservoir, and therefore the source of infection for vector fleas, was reduced to a point where it was not detected.

Comparative costs of the two programs are again a matter of speculation. A thorough rat poisoning and dusting operation would require at least twice the time needed to complete one dusting cycle. Since labor is the major expenditure of such programs, the final expense could be twice that of the dusting program. This assumes, of course, that a single dusting cycle would successfully control the ectoparasites, a premise which is not indicated by the evidence. If two or more dusting cycles were found necessary the costs of the programs should amount to approximately the same figure. The savings to residents of control areas resulting from the rat poisoning program may not be a consideration in evaluating the effectiveness of disease control programs. But it appears that should two equally effective methods be available, the method of choice should be the one which yields the greatest overall benefit. The eradication-type program has three distinct advantages over the dusting program: greater reduction in the source of human infections with murine typhus, better acceptance by the public, and additional savings which result from the elimination of rats.

A third method of murine typhus control which has received some consideration is the elimination of rats by poisoning alone and omitting the DDT dusting to control ectoparasites. Such a program has exactly the same public appeal as the eradication programs, but has some serious deficiencies. Complete rat elimination was never accomplished in the experimental eradication area, and it is highly improbable that it can be achieved over sizable areas. In addition, infected vectors parasitic on the rats poisoned could remain in the area and constitute a hazard to man for many months. The additional expense involved in dusting rat runs concurrently with the poisoning operations is so small that its omission seems impractical.

Incidence in Other Feral Animals

The cotton rat, *Sigmodon hispidus*, appears to be the feral rodent most likely to establish itself in farm buildings where commensal rats have been eliminated. Its importance as a possible natural reservoir of typhus and the questionable ability of its chief ectoparasites to transmit the disease justified investigation (*25*).

Five hundred and twenty-nine cotton rats were trapped at monthly intervals from several locations in four southwestern Georgia counties from March 1956 to March 1957. Their blood serums were tested for murine typhus antibodies by complement fixation tests, and their ectoparasites were removed and identified. Only 1 cotton rat had a titer indicating previous typhus infection (1:128), while 15 other specimens exhibited lower titers. The most numerous ectoparasites were the cotton rat louse, *Hoplopleura hirsuta* Ferris, the mite, *Haemolaelaps glasgowi* (Ewing), and the cotton rat flea, *Polygenis* (*Rhopalopsyllus*) *gwyni* C. Fox. The peaks of abundance for the cotton rat louse, *H. hirsuta*, and the mite, *H. glasgowi*, coincided and occurred during late winter and early spring. The peaks of abundance for the flea, *P. gwyni*, were in February, April, and June. Based upon a comparison with earlier collections made in 1947–48 by Morlan and co-workers, an extraordinarily warm February in 1957 advanced the time of peak abundance in the case of each of the most numerous ectoparasites. The 5 species of fleas collected totaled 729 specimens; 11 species of mites, 7,108 specimens; 2 species of ticks, 10 specimens; and 2 species of lice, 6,360 specimens. Altogether 14,207 ectoparasites were collected, or 29 ectoparasites per infested cotton rat. Ninety-three percent (488) of the 523 rats had some ectoparasites. Higher percentages of cotton rats were infested by cotton rat fleas and *H. glasgowi* during a year with above-normal rainfall (1947–48) than in a dry year (1956–57), while the opposite was true for the louse, *H. hirsuta.*

The present importance of the cotton rat and its ectoparasites in the epidemiology of rural murine typhus is minor, but certain ecological and economic factors which favor possible increases may change the present situation.

Murine typhus in animals other than commensal rats was studied by Morlan and associates (*26*). Serums from 3,202 animals representing 37 species were tested by complement fixation, and 47 from 12 species were positive. Positive serums were obtained from the opossum, cottontail rabbit, fox squirrel, house mouse, rice rat, cotton mouse, old-field mouse, cotton rat, dog, Florida skunk, weasel, and blue jay. Samples greater than 100 specimens were obtained on opossum, cottontail rabbit, house mouse, cotton mouse, old-field mouse, cotton rat, and Florida skunk. The percent of positive serums from these species varied from 0.5 for the cottontail rabbit to 2.7 for the cotton rat. Sufficient serum samples from gray squirrels, raccoons, domestic cats, and common hens were tested to indicate that these species are rarely, if ever, infected.

Summary and Conclusions

From 1945 to 1957 investigations of murine typhus were conducted in a four-county area of southwestern Georgia. During this period efforts were made to control the disease with DDT applied to rat runs and to eradicate the disease from a rural area by using both DDT applications and the anticoagulant rat poisons. In addition, a wide range of information was obtained on the ecology and vector-host relationships of ectoparasites and commensal rats and other mammals.

The investigations sought to determine the effectiveness of various methods used to control murine typhus, especially in rural areas. Although this purpose was fulfilled in considerable detail, the results obtained from the studies are significant from other aspects. First, it was shown that some commensal rat ectoparasites (*Xenopsylla cheopis* and *Leptopsylla segnis*) can be controlled by DDT dusting, while others (*Ornithonyssus bacoti* and *Polyplax spinulosa*) cannot. This information should be applicable to the control of any disease organism for which commensal rodents serve as the reservoir, particularly plague. The effectiveness of the programs extended for a considerable period following cessation of operations, indicating that periodic short-term operations would probably maintain the control of these diseases indefinitely. Commensal rat populations in rural areas, it was shown, can be controlled very effectively at a reasonable cost. While the elimination of rats is usually considered a part of environmental sanitation and the responsibility of the individual occupants of premises, the effectiveness of rat control is directly proportional to the size of the area freed of these rodents. For this reason, it would probably be advantageous to undertake rat elimination programs on at least a countywide basis.

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