BULLETIN
of the
ILLINOIS NATURAL HISTORY SURVE
HARLOW B. MILLS, *Chief*

Tularemia, Weather, and Rabbit Populations

RALPH E. YEATTER
DAVID H. THOMPSON

Printed by Authority of the
STATE OF ILLINOIS
ADLAI E. STEVENSON, *Governor*
DEPARTMENT OF REGISTRATION AND EDUCATION
C. HOBART ENGLE, *Director*

Volume 25, Article 6 *Urbana, Illinois* *June 1952*

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This paper is a contribution from the Section of Game Research and Management.

(48291—4M—4-52)

FOREWORD

IT IS commonly assumed, by people who are not immediately associated with research, that endeavors in this field of activity can be completed in a short time and that findings of value will always accrue. This assumption is often, but not by any means always, valid. Further, short-term researches almost universally have their base in painstaking studies which have progressed over a long period, some time previous to the initiation of the short-term observations. Values which result from research studies are often so closely intertwined with time that these values do not become significant until observations have been continued over a long period. This is the case in the present important contribution, a study correlating game populations, weather, and human health, and utilizing observations covering about a quarter of a century.

Dr. Thompson was zoologist for the Illinois Natural History Survey from 1923 to 1944 and, since that time, has been Senior Naturalist for the Forest Preserve District of Cook County, Illinois. Because of his earlier training in animal pathology and statistics, he became interested in tularemia soon after the first cases were reported in Illinois. In 1934 Dr. Yeatter, a specialist in research and management of upland game in the Middle West, joined our staff and teamed up with Dr. Thompson to work on the relation of human tularemia to rabbit hunting in Illinois. Dr. Yeatter has been principally responsible for completing the project during the past 10 years and for preparing this manuscript for publication. These men noticed the relationship between mild autumn temperatures and the severe outbreaks of human tularemia which occurred in Illinois following the opening of the rabbit-hunting seasons in 1938 and 1939. Later they learned that Dr. Robert G. Green of Minnesota had already foreseen this relationship from a consideration of the life history of the ticks which transmit the infection from rabbit to rabbit and from a study of the course of the disease in the cottontail.

The following study should be of interest to a great many people.

HARLOW B. MILLS, *Chief*
Illinois Natural History Survey

CONTENTS

Hunters in an uncultivated gray soil prairie area in southern Illinois. This part of the state, which has a large cottontail population, has a relatively high human tularemia rate.

Tularemia, Weather, and Rabbit Populations

RALPH E. YEATTER*
DAVID H. THOMPSON*

TULAREMIA, a disease of rabbits and hares (lagomorphs), rodents, and several other animals, is transmissible to man. In the period 1926–1949, Illinois had more than 3,000 reported cases of human tularemia, about twice as many as any of the other states. The great majority of these Illinois cases were traceable to contact with cottontail rabbits, fig. 1.† Because these rabbits are widely distributed on agricultural lands throughout Illinois, and because they are able to maintain themselves under heavy hunting pressure, they rank among the chief game animals of the state. At one time, cottontail rabbits probably made up about two-thirds of the total game bag of Illinois hunters, but, since the tularemia hazard has become generally recognized, rabbit hunting has lost some of its former popularity. Thus, tularemia is of concern to many thousands of people in Illinois not only because of its relation to public health, but also because of its adverse effect on the sport of hunting.

This paper deals with the relation of human tularemia in different parts of the state and in different years to weather, to the abundance of rabbits, and to some other aspects of its epidemiology. In analyzing the information on tularemia in Illinois, the writers have made an effort to determine the methods of management which would permit Illinois hunters to enjoy the sport of rabbit hunting without undue risk of infection. In a report by the writers (Thompson & Yeatter 1941) at the Seventh Midwest Wildlife Conference, Des Moines, Iowa, December, 1941, and in a Natural History Survey release (Anonymous 1941), the writers stated that the human tularemia rate in Illinois is related to weather at the time of the opening of the hunting season. They added that in years in which the mean date of the first 10 freezing nights of autumn occurs before the opening of the rabbit-hunting season, the tularemia rate among humans in the state is much lower than in other years. Green (1935, 1939) had previously pointed out that in Minnesota rabbits are free of tularemia during the cold months of the year and had suggested delaying the hunting of rabbits until middle or late October as a way of reducing the hazard of tularemia in human beings.

The Illinois records on tularemia and weather for the decade following the publication of the writers' first reports appear to support the conclusion that the tularemia rate and weather are closely related. Also, as was previously indicated (Thompson & Yeatter 1941), it is evident that the tularemia rate in Illinois may be influenced strongly at times by fluctuations of rabbit populations. The principal conclusion resulting from the present study is that, because of certain characteristics of the life history of the principal arthropod vector, the incidence of human tularemia in Illinois can be lowered significantly by delaying the opening of the rabbit-hunting

*Dr. Yeatter holds the title of Game Specialist with the Illinois Natural History Survey. Dr. Thompson, for several years with the Illinois Natural History Survey, is now Senior Naturalist of the Forest Preserve District of Cook County, with headquarters at River Forest, Illinois.

†The Mearns cottontail rabbit, *Sylvilagus floridanus mearnsi* (Allen), is the common rabbit in Illinois. South of the Ozarkian Uplift, in extreme southern Illinois, its range intergrades with that of the Oklahoma cottontail rabbit, S. *f. alacer* (Bangs), according to Hamilton (1943). Other Lagomorpha in Illinois are the swamp rabbit, *Sylvilagus aquaticus aquaticus* (Bachman), distributed in wooded bottomlands of a few southern counties, and the white-tailed jack rabbit, *Lepus townsendii campanius* Hollister, which occurs in small numbers in the northwestern part of the state.

Fig. 1.—A Mearns cottontail rabbit. This rabbit is an important game animal throughout its range from New York to Kansas. In Illinois, it is the reported source of more than 90 per cent of the human tularemia cases.

season until about December 1. Such delay is urgent, particularly in the central and southern parts of the state.

Acknowledgments

The writers are greatly indebted to the Illinois Department of Public Health for detailed records since 1926 on the distribution of tularemia cases in Illinois and to the United States Public Health Service for information on the prevalence of tularemia in other parts of the country. They are indebted also to the Wisconsin Conservation Department for permission to use its records of the annual kill of cottontail rabbits in Wisconsin, to the United States Forest Service for census data on a southern Illinois area, and to Joe L. Mote of Watseka, Illinois, for bag records and field notes.

History of Tularemia

Tularemia was discovered in 1910 by Dr. George W. McCoy of the United States Public Health Service in the ground squirrels of Tulare County, California (McCoy 1911; Francis 1937). The disease was named in 1920 by Dr. Edward Francis (1921, 1937), also of the United States Public Health Service, after he had established the identity of the ground squirrel disease with an outbreak of "Deerfly fever" in man in Utah. The essential facts about tularemia have been worked out entirely by American investigators. The causative organism is a bacterium, *Pasteurella tularensis* (McCoy & Chapin) Bergey *et al.* (McCoy & Chapin 1912; Breed, Murray, & Hitchens 1948). In spite of the short history of tularemia, it is believed that this disease is not new but

is an old one which was not identified until comparatively recent years. Since 1925 it has been reported from all states except Vermont, as well as from Canada, Alaska, Mexico, and several countries in Europe, Asia, and Africa.

Tularemia in Wildlife

Burroughs *et al.* (1945) have listed 47 kinds of mammals and birds, distributed chiefly in North America, Europe, and Asia, in which natural infection with tularemia has been shown by laboratory tests. Various groups of lagomorphs and rodents make up more than three-fourths of their list. Also included are certain gallinaceous birds, raptorial birds, and carnivores, as well as a few domestic animals.

A few years ago, wildlife pathologists of the University of Minnesota and the United States Bureau of Biological Survey (now the Fish and Wildlife Service), co-operating with the Minnesota Department of Conservation, studied the relation of tularemia to the welfare of several wildlife species in Minnesota. As a result of these studies, Green (1939) reported that cottontail rabbits are highly susceptible to tularemia, and that infected cottontails invariably die, usually within a week after the onset of the disease. He found that snowshoe hares are resistant to the disease and that they seldom die from it. Jack rabbits prove rather susceptible when exposed, but, among wild jack rabbits in Minnesota, tularemia is apparently rare.

Green & Wade (1929) reported a fatal tularemia infection in the bob-white, *Colinus virginianus* Linnaeus; Green & Shillinger (1932) found the disease in the ruffed grouse, *Bonasa umbellus togata,* and the sharp-tailed grouse, *Pediocetes phasianellus.* Green (1939) stated that the ring-necked pheasant is highly resistant to infection, but that muskrats "suffer from a highly fatal infection." He reported that all kinds of mice, squirrels, and other small rodents in Minnesota are susceptible, and suggested that mice may be an important reservoir of the disease in the wild.

Green & Wade (1928) found that domestic cats contracted tularemia when fed the carcasses of infected guinea pigs. Green (1942) stated that dogs appear to be almost entirely immune. Waller (1940), however, reported agglutination tests positive for tularemia in blood samples of a dog which became sick after feeding on a diseased rabbit. Downs *et al.* (1946) were successful in infecting a number of laboratory dogs by injection of virulent tularemia organisms, but reported that dogs were less susceptible to the disease than most laboratory animals and that they were often able to localize the infection.

Lillie & Francis (1936) reported as follows on attempted experimental inoculation of red foxes: "In 1934 four red foxes (*Vulpes fulva*) were obtained. One (7484) was injected subcutaneously with infected guinea pig spleen and culture (Omo strain), and died 13 days later. He refused to eat during the entire period. There was a diarrhea during the last 2 days of life. Two other foxes died 2 months after the subcutaneous inoculation of 7760 and after the first infectious feeding of 7761. Both of these animals had had noisy labored respiration; the first for some 4 weeks, the second for 3 or 4 days before death.

"*B. tularense* was recovered directly from the blood of 7484, and inoculation of various organs of all three reproduced tularaemia in guinea pigs and cultures were recovered."

Human beings sometimes become infected with tularemia through being bitten, scratched, or clawed by dogs, cats, or other flesh-eating animals that have become contaminated with the tissue or blood of infected wildlife.

A considerable number of animal species in which natural infection has not been proved have been reported as probable sources of human tularemia. Francis (1937) mentioned as suspected carriers the coyote, red fox, deer, ground hog, tree squirrel, skunk, sage hen, bull snake, and hog. Of domestic rabbits, Francis stated, "Rabbits raised under domestic conditions in rabbitries and hutches, although highly susceptible, have not been found naturally infected, due probably to their freedom from ticks."

Tick and Insect Vectors

Tularemia is spread among wild animals largely by the bites of ticks and insects.

Fig. 2.—Rabbit tick, *Haemaphysalis leporis-palustris* (Packard). *Top,* male; *center,* female; *bottom,* female, engorged. The rabbit tick is the chief agent in the spread of tularemia among rabbits and is an important carrier of the disease in other kinds of wildlife.

Infection in carnivorous mammals and birds may, of course, come from eating diseased prey. Also, it seems probable that certain aquatic mammals, and possibly other forms, sometimes contract the disease from water that is contaminated with *Pasteurella tularensis.* For example, the findings of Jellison *et al.* (1942) suggest that water-borne disease organisms were the source of a tularemia outbreak among beavers in Montana in 1939 and 1940.

Studies by Parker *et al.* (1951) indicate that contamination of streams and mud with tularemia organisms is widespread in the northwestern United States, and that fatal infections of muskrats and beavers with tularemia probably have occurred there in recent years.

The rabbit tick, *Haemaphysalis leporis-palustris* (Packard), fig. 2, is the chief arthropod vector of tularemia in the wild. Francis (1937) stated, "The disease . . . . is spread from rabbit to rabbit principally by the rabbit tick, *Haemaphysalis leporis-palustris,* but also by other blood-sucking arthropods—ticks, lice, and fleas. The rabbit tick, the rabbit louse, and the rabbit flea do not bite man, and therefore they are not a source of human infection."

Green (1942) reported that the rabbit tick was principally responsible for the spread of tularemia among wild animals and birds in Minnesota.

Two other ticks, the American dog tick, *Dermacentor variabilis* (Say), fig. 3, and the Rocky Mountain wood tick, *D. andersoni* Stiles, fig. 4, are known vectors of tularemia. Both are sources of the disease in man as well as in various species of wildlife. The American dog tick, *D. variabilis* (also called wood tick), is distributed in the eastern United States, in the Mississippi River valley, and in some of the Plains states as well as in western California, Canada, and Alaska (Cooley 1938). Green (1942) reported that the most common mode of human tularemia infection in Minnesota appeared, at the time he wrote, to be the bite of a "wood tick" (American dog tick) and the second most common the cleaning of an infected rabbit. He found that the adult dog ticks that carry tularemia are those that have become infected during immature stages while feeding on diseased mice or other small rodents.

Fig. 3.—American dog tick, *Dermacentor variabilis* (Say). *Top,* male; *center,* female; *bottom,* female, engorged. This tick is widely distributed in North America; its principal range is east of the Rocky Mountains. It is a source of tularemia in humans and probably in various wild and domestic animals.

Fig. 4.—Rocky Mountain wood tick, *Dermacentor andersoni* Stiles. *Top,* male; *bottom,* female. This tick is a source of tularemia in humans and probably in domestic animals and wildlife. It is found in western parts of the North American continent.

Bell (1945) reported that a natural barrier, apparently a bactericidal action of the ticks' guts, keeps infection among dog ticks at a relatively low level. Green (1942) reported a maximum of only 1 infected to about 2,500 uninfected dog ticks in numerous tick samples collected in Minnesota. He noted that dog ticks in Minnesota go into a resting period in July and remain dormant until the following spring, and that they cause infection principally in May and June, just previous to becoming dormant.

The Rocky Mountain wood tick is distributed in southwestern Canada and in the western United States from the arid zone east of the Rocky Mountains westward to central Washington, central Oregon, and eastern California. Both immature and adult stages have been found

on a wide variety of mammals and birds (Cooley 1938). The adult stage has been reported as a source of human tularemia in several western states. Wood ticks are believed to have caused a tularemia outbreak among range sheep in Montana (Philip, Jellison, & Wilkins 1935).

Several kinds of insects are known to be carriers of tularemia. Prince & McMahon (1946) stated that the disease has been transmitted under experimental conditions by the bites of several insects, including deer flies, *Chrysops discalis* Williston, stable flies, *Stomoxys calcitrans* (Linnaeus), bed bugs, *Cimex lectularis* Linnaeus, and mosquitoes, *Aedes aegypti* (Linnaeus).

Lice and fleas, mentioned as vectors by Francis (1937), appear to be potentially important in the dissemination of tularemia in the northern states because they remain active in winter when most arthropod vectors are dormant. Ecke (1948) found that flea populations on Illinois cottontails were higher in winter than at other seasons. Evidence apparently is lacking, however, that either fleas or lice frequently transmit tularemia. Prince & McMahon (1946) reported that guinea pigs used in their transmission experiments remained negative for tularemia after exposure during 32 days to infected rat fleas, *Xenopsylla cheopis* (Rothschild), and California ground squirrel fleas, *Diamanus montanus* (Baker). They concluded that the two species of fleas tested do not play an important role in the spread of the disease. Green (1942) stated, "Fleas are found on rabbits in southern Minnesota during the winter; but, although these insects can transmit tularemia, they appear to do so rarely."

Hopla (1951) found that tropical rat mites, *Bdellonyssus bacoti* (Hirst), retained tularemia organisms for considerable periods after feeding on infected mice. Normal mice became infected when they crushed infected mites orally, but not when they were bitten by the mites.

Tularemia in Man

Francis (1937) stated that wild rabbits and hares are the source of more than 90 per cent of all human tularemia cases in the United States. Humans generally become infected from contact of the bare hands with the flesh or blood of infected rabbits or from eating infected rabbit flesh that is insufficiently cooked. Usually infection from handling a diseased rabbit develops at the site of a scratch or puncture in the skin, but occasionally it develops in the eye as a result of contact with hands or of spattering of washings during cleaning. There is considerable evidence that the disease organism also is able to penetrate the unbroken human skin.

Francis (1937) described a typical tularemia case as follows: "About 3 days after exposure to infection, illness begins with headache, chilliness, vomiting, aching pains all over the body, and fever. The patient thinks that he has the 'flu' and goes to bed. The sore on the hand develops into an ulcer. The glands at the elbow or in the armpit become enlarged, tender, and painful, and later may develop into an abscess. There is sweating, loss of weight, and debility. Illness lasts about 3 weeks and is followed by a slow convalescence covering a period of 2 or 3 months. Most patients recover without any bad after effects, but about 5 percent die, especially if the case is complicated by pneumonia." Although there is no evidence of a natural immunity in man, persons who have recovered from the disease are permanently immune.

In regard to the diagnosis of the disease, Francis (1937) wrote: "The history of tick-bite, fly-bite, or wild rabbit contact especially, or contact with other animals, when coupled with fever, an ulcer on the skin, and regional lymph-node enlargement, should call attention to tularaemia. Diagnosis is made conclusive by obtaining agglutination of *Bacterium tularense* [*Pasteurella tularensis*] by the patient's serum or by obtaining a culture of the organism from the patient's ulcer or lymph nodes following guinea pig inoculation, or by obtaining a positive skin reaction using an antigen prepared by Foshay of Cincinnati for intradermal injection."

As will be discussed later, treatment of tularemia in man has been facilitated in recent years by the use of antibiotics.

Distribution in the United States. —It will be evident from fig. 5, showing the distribution of 23,921 cases of tularemia reported in the United States during

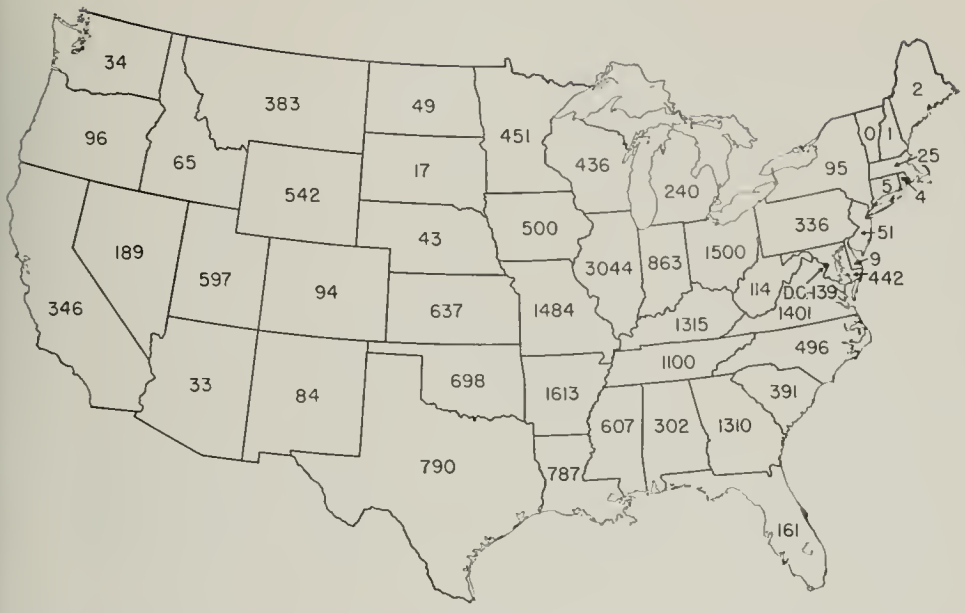


Fig. 5.—Total numbers of reported human tularemia cases in the various states during the period 1924–1949. Data from records of the United States Public Health Service.

the period 1924–1949, that the largest number of cases occurred in states lying in the central and south central portions of the eastern half of the country. Jellison & Parker (1945), who emphasize the importance of cottontail rabbits as a source of tularemia in humans, pointed out that cottontails and closely related forms are the only kinds of wild rabbits native to much of the region mentioned above.

Table I.—States that reported a total of 500 or more cases of tularemia, 1924–1949.*

State	Number of Cases
Illinois	3,051
Arkansas	1,613
Ohio	1,500
Missouri	1,484
Virginia	1,401
Kentucky	1,315
Georgia	1,310
Tennessee	1,100
Indiana	863
Texas	790
Louisiana	787
Oklahoma	698
Kansas	637
Mississippi	607
Utah	597
Wyoming	542
Iowa	500

*Data from United States Public Health Service records except Illinois figure, which is from Illinois Department of Public Health and higher than figure from federal agency.

The states which, according to the records of the United States Public Health Service, reported 500 or more cases of tularemia in the period 1924–1949 are listed in table 1. Illinois, with more than 3,000 cases, reported the largest number, followed by Arkansas with 1,613 and Ohio with 1,500 cases. Although Illinois had the largest human population among the 17 states listed, more than one-half of all tularemia cases reported in Illinois in 1936–1949 were from counties in the southern third of the state, which had only about 12 per cent of the state's population.

Preliminary studies indicated that the human tularemia rate in Illinois and nearby states tended to fluctuate, but it was evident that the particular years in which increases, or decreases, occurred often were not the same in all parts of a geographic region. For example, in one year, 1938, there was a decline of about 50 per cent in the tularemia rate in the northern Great Lakes states, but at the same time there was a severalfold increase in Illinois and the regions adjoining it on the east and west. Later, in 1941,

Fig. 6.—Four general regions of the United States which exhibit distinctive trends and seasonal distribution of human tularemia.

when tularemia declined in Illinois, Indiana, and Iowa, there was a moderate increase in the states to the north.

With respect to human tularemia rates and seasonal distribution, the United States may be divided conveniently into four major regions, namely, Northern, Central, Southern, and Western, fig. 6. Trends in the annual tularemia rates during the period 1935–1949 in these four

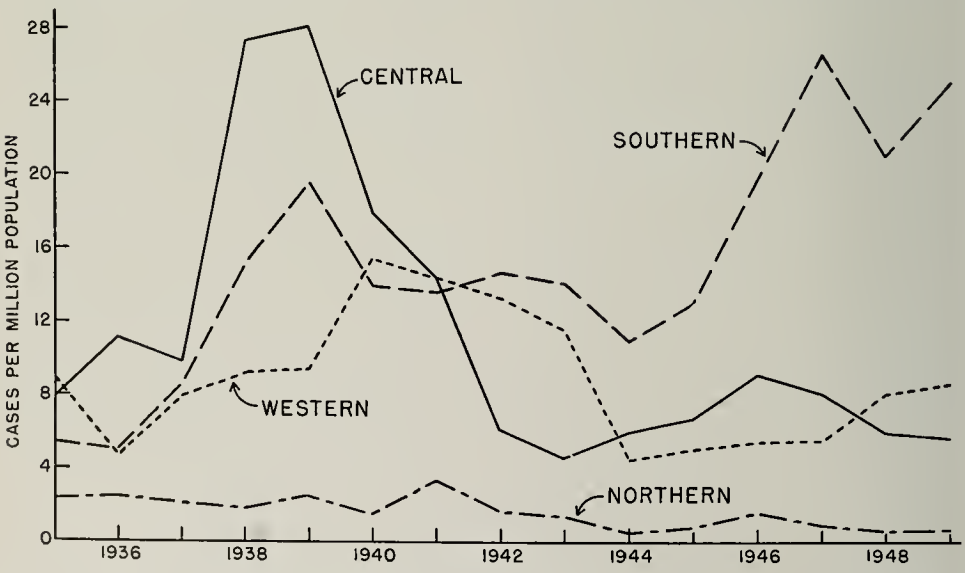


Fig. 7.—Trends in human tularemia rates during the period 1935–1949 in the four regions of the United States shown in fig 6. Data on which this graph is based are from records of the United States Public Health Service.

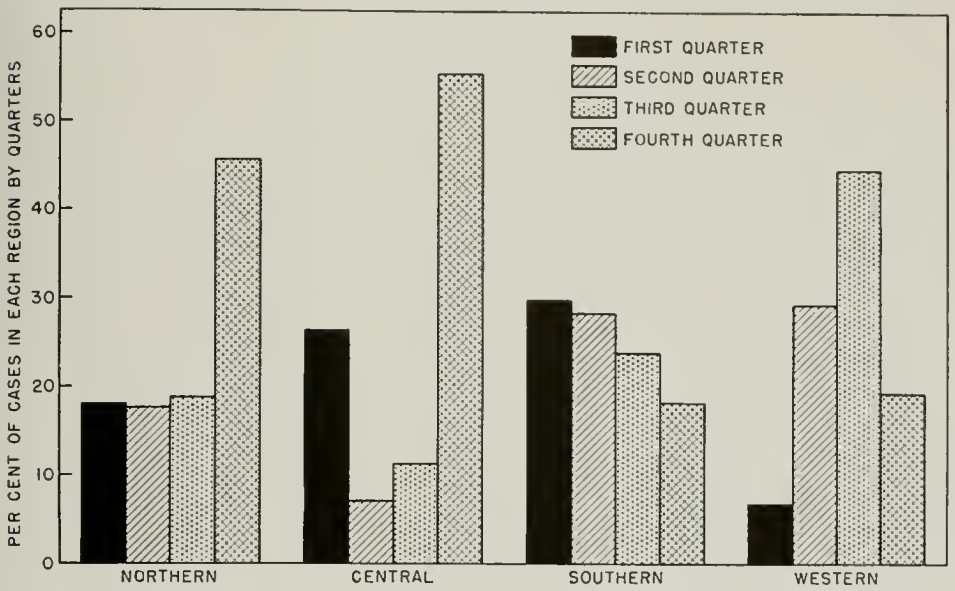


Fig. 8.—Distribution of reported human tularemia cases by quarters of the year during the period 1939–1949 in the four regions of the United States shown in fig. 6. Data on which this graph is based are from records of the United States Public Health Service.

regions are shown in fig. 7. The seasonal distribution of tularemia in these regions is shown in table 2 and fig. 8.

In the Northern and Central regions the majority of cases occur during late autumn and early winter. Rabbits, which are hunted at that time, cause most of the cases. As indicated by table 3, furbearers, squirrels, and upland game birds contribute a few cases. During other seasons, these regions show moderate numbers of cases that, presumably, result from bites of ticks or insects, from chance infections by a variety of mammals or birds, both wild and domestic, or from a small amount of year-round hunting.

In the Southern Region, the human tularemia rate is fairly uniform throughout the year, indicating several sources of infection, the most important of which are rabbits, ticks, and insect vectors. Francis (1937) recorded 65 cases of tularemia in the southern states, chiefly from March through July, due to contact with dog ticks, *Dermacentor variabilis*. Pullen & Stuart (1945) reported that 176 (92.1 per cent) of 191 tularemia cases for which the apparent source was recorded in Louisiana during a 16½-year period gave a history of contact with rabbits. In this region, year-round hunting probably plays an important part in transmission of tularemia to human beings.

The human tularemia rate in the Western Region is highest in summer. Because the principal insect and tick vectors in this region are most active from late spring to late summer, it appears that arthropods may play a relatively greater part in transmitting tularemia to humans there than in the Northern and Central regions. Wood ticks, *Dermacentor andersoni*, were reported by Francis (1937) to have caused more than 50 cases in Montana and surrounding states. According to the United States Public Health Service (Anonymous 1940), sheep handlers have occasionally become infected from contact with wood ticks or tick feces in the wool. Jellison (1950) listed, for the western states, 158 cases of tularemia probably caused by deer fly bites, and showed that the distribution of these cases corresponded roughly with the distribution of the deer fly species, *Chrysops discalis* Williston. Jellison *et al.* (1950) reported contamination with *Pasteurella tularensis* organisms of certain natural waters in Montana and also a few cases of human tularemia caused by a contaminated domestic water supply.

Table 2.—Summary of reported tularemia cases in four major regions of the United States, by quarters and years, 1939–1949. (Data from annual reports of the United States Public Health Service on the incidence of communicable diseases.)

Year	Northern Region[1]					Central Region[2]					Southern Region[3]					Western Region[4]				
	Quarter				Total for Year	Quarter				Total for Year	Quarter				Total for Year	Quarter				Total for Year
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4	
1939	5	9	9	57	80	291	36	90	1,007	1,424	209	153	101	142	605	12	29	57	30	128
1940	10	8	11	24	53	368	45	78	444	935	176	103	86	74	439	10	70	105	29	214
1941	21	15	15	64	115	127	37	68	509	741	105	121	111	90	427	12	68	86	33	199
1942[5]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1943	6	11	16	16	49	91	32	38	77	238	134	167	90	50	441	6	70	64	19	159
1944	6	4	4	4	18	40	18	32	220	310	78	121	95	49	343	3	16	34	9	62
1945	6	4	11	7	28	117	36	46	150	349	116	102	112	78	408	3	25	32	11	71
1946	11	12	9	24	56	76	44	56	294	470	152	143	176	148	619	11	22	25	17	75
1947	11	5	10	6	32	180	52	84	106	422	261	233	201	120	815	6	13	37	20	76
1948	3	9	2	6	20	82	29	63	130	304	146	230	147	134	657	6	17	55	34	112
1949	6	7	2	8	23	74	54	62	100	290	266	203	197	119	785	14	26	47	33	120
Total	*85*	*84*	*89*	*216*	*474*	*1,446*	*383*	*617*	*3,037*	*5,483*	*1,643*	*1,576*	*1,316*	*1,004*	*5,539*	*83*	*356*	*542*	*235*	*1,216*

[1]*Northern Region:* Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota.
[2]*Central Region:* New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia, Ohio, Indiana, Illinois, Kentucky, Iowa, Missouri, Nebraska, Kansas.
[3]*Southern Region:* North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas.
[4]*Western Region:* Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California.
[5]Records for 1942 are omitted because quarterly summaries are lacking. The total numbers of reported cases for 1942 are as follows: Northern Region, 58; Central Region, 317; Southern Region, 464; Western Region, 185.

Jack rabbits, *Lepus* spp., are the reported source of a number of cases in the Western Region. These rabbits also are important hosts of ticks and probably of biting flies that carry the disease (Jellison & Parker 1945). Jellison (letter of April 24, 1951, from Hamilton, Montana) states, "Cottontails have not been as important in this area as other sources of infection."

Distribution in Illinois.—Records of the Illinois Department of Public Health indicate that cottontail rabbits are responsible for the great bulk of human tularemia in Illinois. According to Sharp (1939) all but 2 of 459 reported cases in the state in 1938, during a severe outbreak of the disease, were traceable to contact with cottontail rabbits. McDaniels (1943) stated that cottontails cause more than 95 per cent of the human tularemia cases in Illinois. Other mammals, birds, ticks, and blood-sucking insects probably serve as the source of infection for most of the other cases, as numerous infections have been traced to them elsewhere in the United States.

Recent studies by Jackson (1946) in Indiana and Morgan (1949) in Wisconsin, table 3, show somewhat higher percentages of cases caused by vectors other than rabbits reported for these states than for Illinois. As has already been shown, the proportion of tularemia cases caused by the several kinds of known vectors varies with different sections of the country.

The mortality rates from human tularemia cases reported in Illinois during the period 1926–1951 averaged 5.7 per cent, table 4. Considerable variation in the mortality rates was apparent from year to year. It is of interest in this regard that Philip & Davis (1935), Green (1943), and others isolated several strains of tularemia from naturally infected animals. These strains differed widely in virulence. Green's work indicated that the virulence of the disease depended largely on the kind of animal from which it came. For example, he found that the virulence of tularemia from infected grouse was considerably lower, when measured by the

Table 3.—Reported sources of human tularemia in Wisconsin (379 cases in which the cause was reported) and Indiana (123 cases). Data from Morgan (1949) and Jackson (1946).

Reported Source of Infection	Wisconsin		Indiana	
	Number of Cases	Per Cent of Total	Number of Cases	Per Cent of Total
Mammal	*340*	*89.7*	*117*	*95.1*
Rabbit	305	80.5	108	87.8
Muskrat	10	2.6	2	1.6
Cat	9	2.4	1	0.8
Dog	8	2.1	—	—
Squirrel	4	1.1	5	4.1
Skunk	2	0.5	—	—
Horse	2	0.5	—	—
Opossum	—	—	1	0.8
Upland Game Bird	*11*	*2.9*	*1*	*0.8*
Partridge, pheasant, or prairie chicken	11	2.9	—	—
Pheasant	—	—	1	0.8
Arthropod	*27*	*7.1*	*5*	*4.1*
Tick	24	6.3	4	3.3
Deer fly	3	0.8	—	—
Sweat bee	—	—	1	0.8
Water	*1*	*0.3*	—	—
Total	*379*	*100.0*	*123*	*100.0*

Table 4.—Data on human tularemia reported by the Illinois Department of Public Health 1926–1951.

YEAR	CASES	DEATHS	PER CENT MORTALITY
1926.....	1	—	—
1927.....	14	—	—
1928.....	10	—	—
1929.....	36	1	2.8
1930.....	139	2	1.4
1931.....	126	4	3.2
1932.....	134	4	3.0
1933.....	172	9	5.2
1934.....	134	11	8.2
1935.....	69	4	5.8
1936.....	91	6	6.6
1937.....	109	5	4.6
1938.....	459	32	7.0
1939.....	485	42	8.7
1940.....	272	23	8.5
1941.....	106	6	5.7
1942.....	67	1	1.5
1943.....	55	1	1.8
1944.....	91	10	11.0
1945.....	131	6	4.6
1946.....	97	9	9.3
1947.....	123	1	0.8
1948.....	57	2	3.5
1949.....	73	0	0.0
1950.....	80	2	2.5
1951.....	74	0	0.0
Total....	*3,205*	*181*	—
Average.	—	—	5.7

survival time of inoculated guinea pigs, than that from rabbits. After serial passage of these strains through guinea pigs, however, the virulence of the two strains became identical.

According to a publication of the Illinois Department of Public Health (Anonymous 1939) tularemia in man "may be mild in character although greatly reducing physical efficiency. For that reason a great many cases undoubtedly escape notification. . . . [The disease is] probably considerably more prevalent in Illinois than case reports indicate."

Hicks (1942) has suggested that some rabbit hunters, as a result of mild infections, may acquire a degree of immunity to tularemia. He wrote: "If there is such a thing as partial or complete immunity, it may be due to a former infection so mild as to have gone unrecognized, or, more likely, to resistance acquired by frequent but slight inoculations obtained through being bitten by ticks or other vectors."

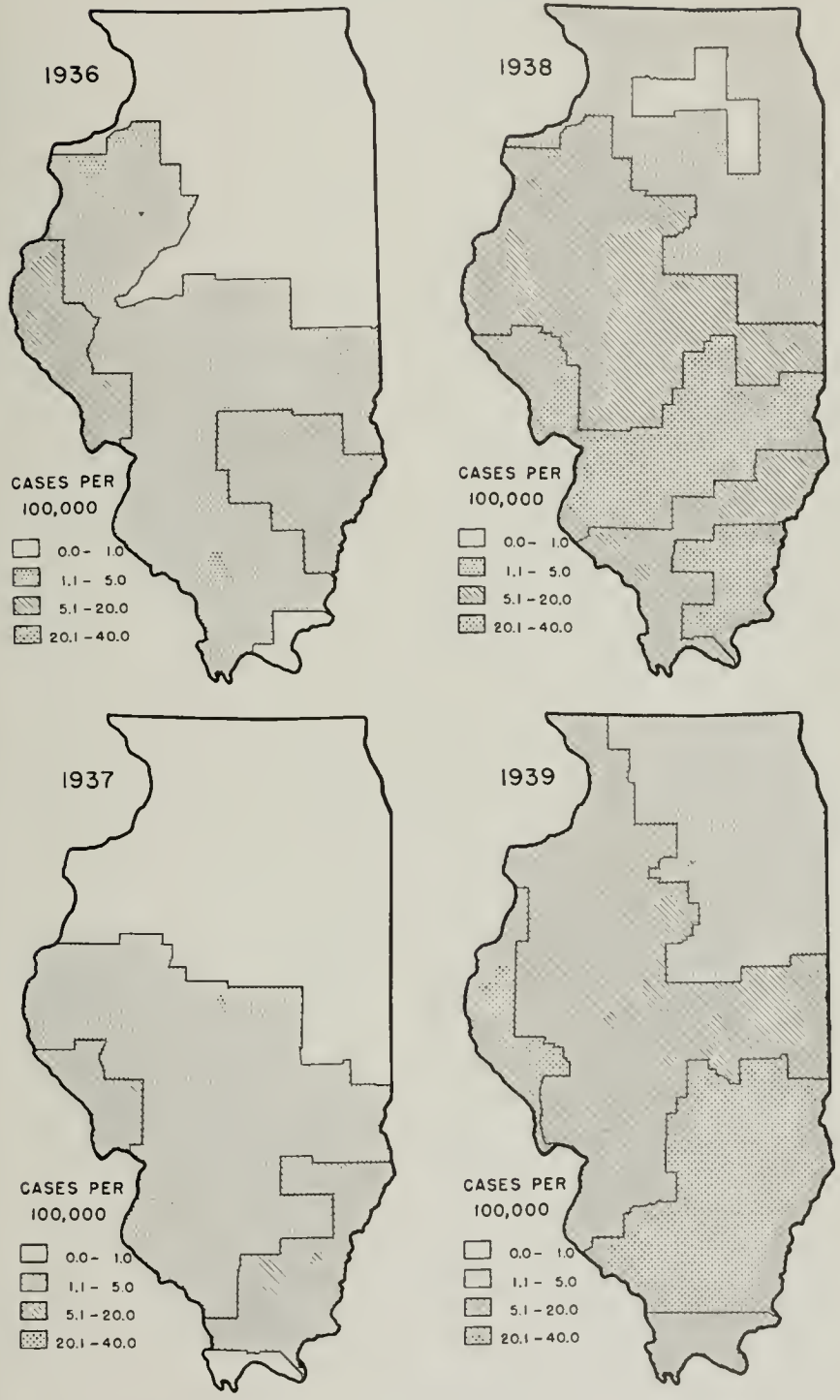
The first known case of human tularemia in Illinois was reported in 1926. By 1930 the annual total of reported cases exceeded 100. A summary of the data on tularemia in Illinois during the period 1926–1951 is shown in table 4. The small number of cases reported early in this period probably reflects lack of experience on the part of many physicians in identifying the disease.

The distribution of human tularemia in Illinois in each year of the 14-year period 1936–1949 (the years of most intensive study of rabbit populations in relation to incidence of human tularemia) is presented in figs. 9–22. Because the number of cases in most counties was too small to be treated statistically, and because hunters commonly go into neighboring counties to hunt, the data have been "smoothed" in order to determine general trends in prevalence of the disease over the state. This "smoothing" of the data was done for each county by averaging the number of cases and the populations with comparable data for all adjoining counties.

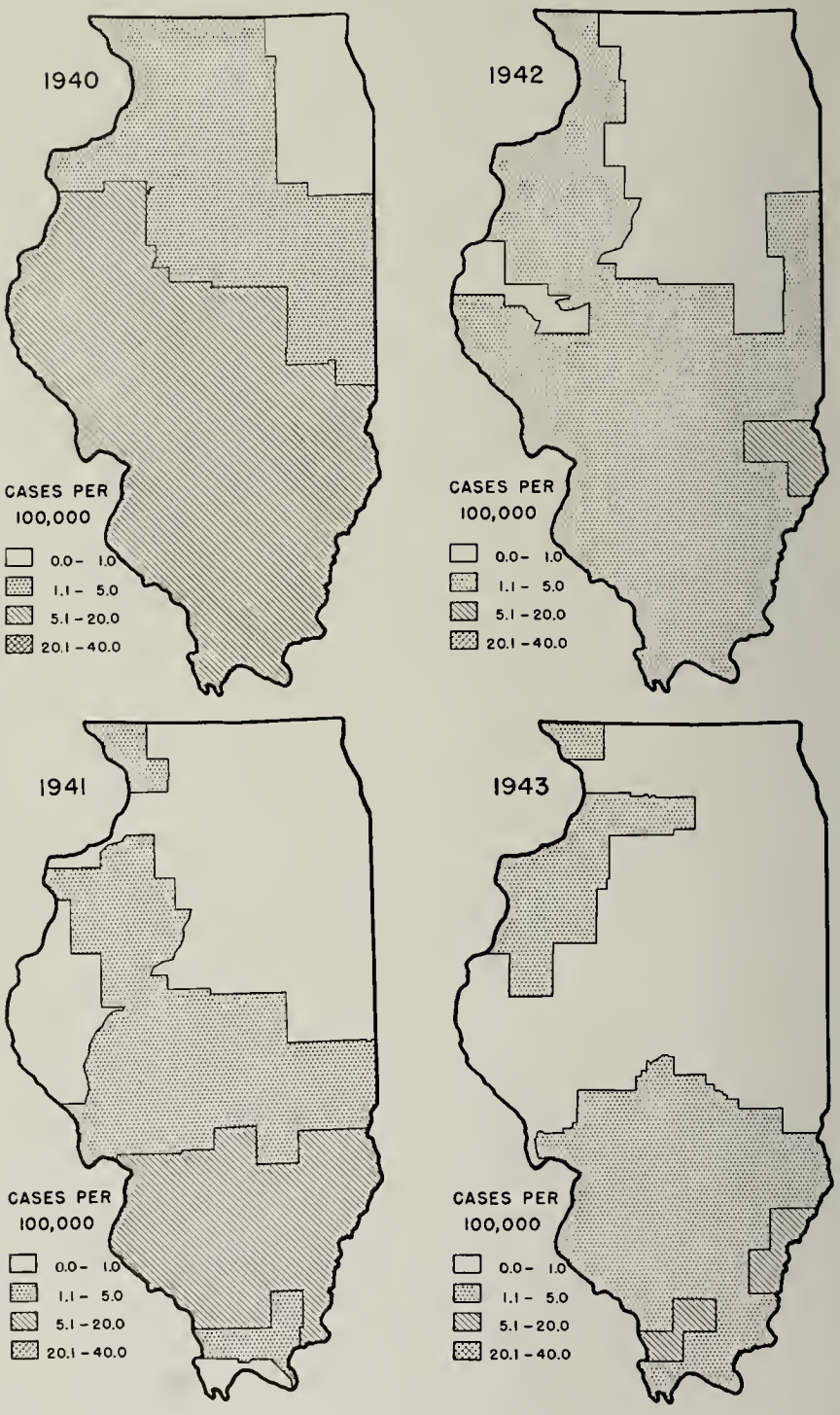
When the tularemia rate was calculated on the basis of numbers of hunting licenses sold in the various counties, rather than the total population, the trends were essentially the same and need not be shown here.

An inspection of the 14 maps in figs. 9–22 shows that tularemia rates among humans in the south and central parts of the state are much higher than in the northern part. In each of these years there were blocks of counties in the south central region where the rates were 10 to 20 times as great as in the northeast part of the state. Areas of highest rates follow about the same pattern from year to year and are located in two general regions: (a) a region consisting of 15 to 25 counties in the southeast part of the state and (b) a region consisting of a smaller block of counties along the lower course of the Illinois River and up the west side of the state along the Mississippi River.

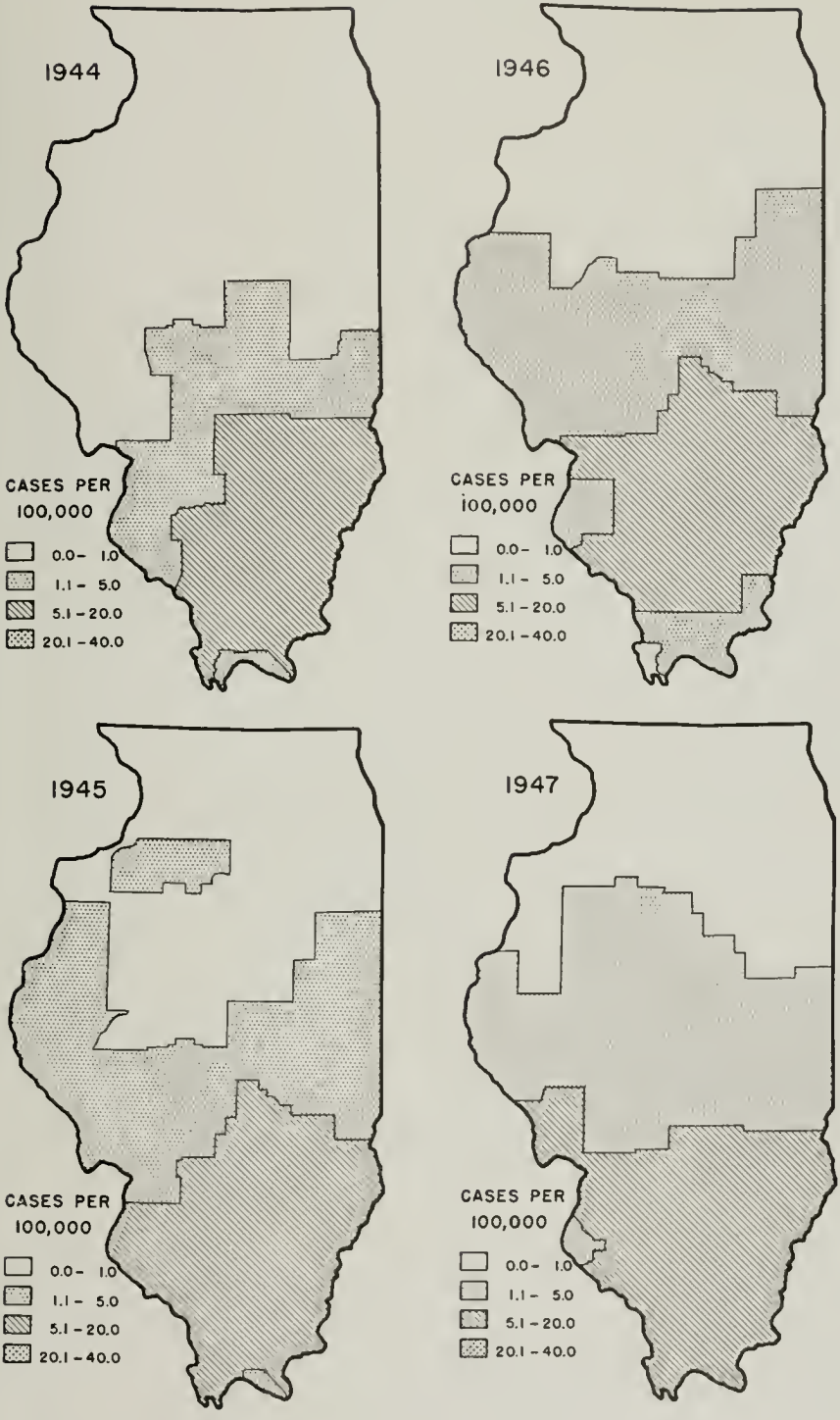
These regions correspond rather closely with the sections of the state listed by Case & Myers (1934) as having the highest percentages of idle land, that is, land not under cultivation. The first-named region consists for the most part of what is known as the gray soil prairie, where soils are light colored and fertility is relatively low.



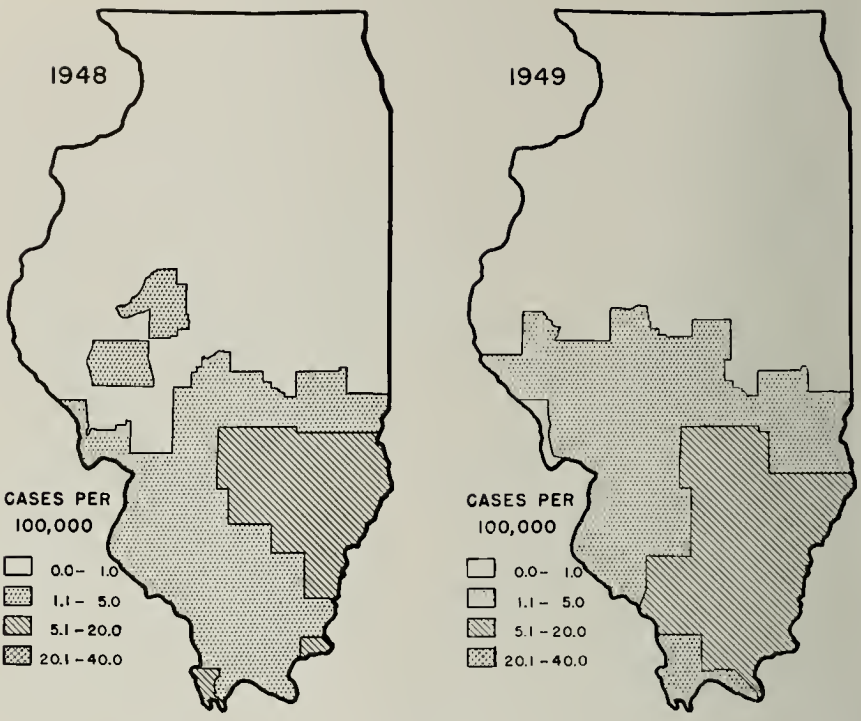
Figs. 9–12.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1936–1939.



Figs. 13–16.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1940–1943.



Figs. 17–20.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1944–1947.



Figs. 21–22.—Distribution of human tularemia cases per 100,000 population in Illinois for the years 1948–1949.

Here, there are scattered wood lots, overgrown stream banks, hedges, and, during periods of low agricultural prices, many fields that are allowed to lie fallow for one or more years at a time. The second region is dissected by a number of small streams draining into the Illinois and Mississippi rivers. As a result, it has a high percentage of forested and uncultivated land.

The tularemia rates in the above-named regions are among the highest in the United States. The prevalence of tularemia in these regions probably is indirectly related to the comparatively high rabbit populations found there. Green, Evans, & Larson's (1943) study of rabbit tick populations on snowshoe hares in Minnesota showed that when hares were abundant the average number of ticks per hare was high, but when hares were uncommon the average number was low. Possibly both the relatively high rabbit populations and dense ground cover in extensive areas of southern Illinois favor the survival of rabbit ticks, thus contributing to the spread of tularemia.

Weather and Tularemia

The interrelationships of ticks and tularemia to the cottontail and snowshoe hare in Minnesota were studied in detail for a number of years by the late Dr. Robert G. Green and his associates. They found that rabbit ticks were the principal means by which tularemia was spread from rabbit to rabbit in Minnesota and that these ticks left the rabbits by mid-autumn to go into hibernation. Green, Evans, & Larson (1943) reported that most hares and rabbits were found free of ticks after November 1, although occasional individuals might carry ticks in December, January, and even in February.

Green (1935, 1939) reported that after cold weather has caused the ticks to leave the rabbits, and after an additional week during which infected cottontails die, hunting is comparatively safe. He recommended that hunting in Minnesota be delayed until middle or late October.

Earlier in this paper it was pointed out that in 1938 there was a marked decline

in human tularemia in the northern Great Lakes states and a great increase in Illinois and states adjoining it on the east and west. In Illinois there was a considerable increase in the number of rabbits between the autumn of 1937 and the autumn of 1938, but it did not seem great enough to account for the eightfold increase in the number of tularemia cases reported in the 1938 hunting season. Inasmuch as there had been no shifts in the date of opening of the rabbit season in any of the North Central states, it occurred to us that these changes in tularemia rates might be due to differences in temperatures about the time of the opening of the season, as well as to changes in rabbit abundance.

Although the percentage of infected rabbits apparently declines sharply throughout the state soon after November 11 (the opening date of the rabbit-hunting seasons in recent years) the peak month for cases reported to the Illinois Department of Public Health is December, table 5. It should be explained here that tularemia cases are usually listed for the month in which they are reported and not the month of infection. Francis (1937) cites 45 Illinois tularemia cases for which the exact month of onset is accurately recorded, as follows: October, 1 case; November, 23 cases; December, 18 cases; and January, 1 case. We suppose that the apparent discrepancy arises from (a) delays between killing and eating rabbits (cold storage or freezing does not prevent infection), (b) incubation period for the infection, (c) delay in consulting a physician, (d) time for making the diagnosis, and (e) time for making the report after diagnosis.

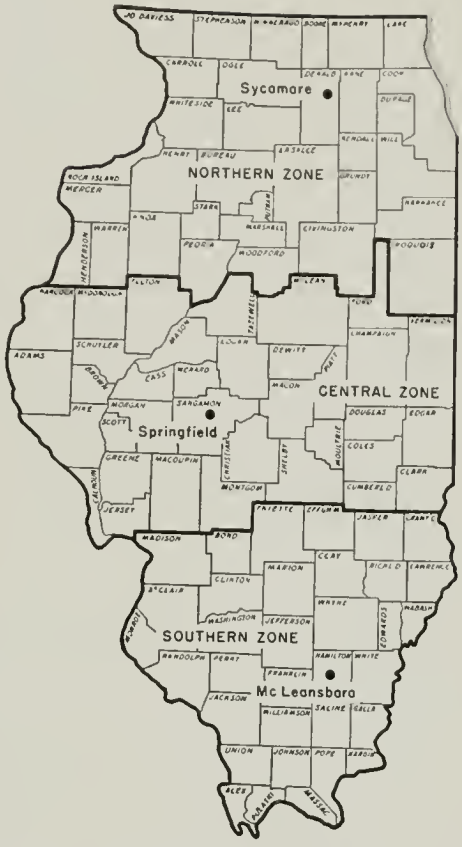


Fig. 23.—The three hunting zones of Illinois established by the state Game Code and the location of United States weather stations whose records were used in this paper as representative of each zone.

Table 5.—Distribution of Illinois cases of human tularemia, by months, 1926–1949.

Month	Cases	Per Cent of Total
July	57	1.9
August	50	1.6
September	51	1.7
October	69	2.3
November	318	10.4
December	1,507	49.4
January	603	19.8
February	175	5.7
March	76	2.5
April	46	1.5
May	53	1.7
June	46	1.5
Total	*3,051*	*100.0*

To learn whether the prevalence of human tularemia in Illinois is associated with temperatures preceding the opening of the rabbit season, we correlated the number of cases reported in the November-February period following the opening of each hunting season, 1926–1949, with the mean or average date of the first 10 freezing nights. A freezing night was defined arbitrarily as 27 degrees F. or colder. This method of studying the relation of the incidence of human tularemia to weather was devised several years ago by the writers (Anonymous 1941). It appears to result in a more satisfactory

correlation than any of several other methods that were tried.

Illinois, with a north-south length of almost 400 miles, has striking differences in climate, and for that reason the game and fish codes recognize three zones of about equal area: Northern, Central, and Southern. For making comparisons of the mean dates of the first 10 freezing nights, we chose a representative weather station located near the center of each of these zones. The Sycamore, Springfield, and McLeansboro stations have records covering long periods of years and are not in deep valleys or near large bodies of water. The three zones and the locations of these weather stations are shown in fig. 23.

When the numbers of days between the mean or average dates of these first 10 freezing nights and the dates of the opening of the rabbit-hunting seasons are compared with the numbers of cases of human tularemia for 24 successive years, 1926–1949, it is evident that there is a general correspondence in rises and falls between the two sets of data.

Table 6 shows the mean dates of the first 10 freezing nights for each zone in each of 24 autumns beginning in 1926, when tularemia was first reported in Illinois, as well as the opening dates of the rabbit-hunting season, the number of days between these dates in each year (the three zones averaged), and the numbers of tularemia cases in the November-February periods. The correspondence between the two curves is most striking in recent years, when recognition and reporting of the disease has been general, fig. 24.

For each year of the period 1936–1940, bracketing Illinois' greatest tularemia outbreak, data are available showing the distribution of cases by counties. These data make possible a comparison of average tula-

Table 6.—Dates of rabbit-hunting seasons, average or mean dates of first 10 freezing nights in autumn, and number of human tularemia cases reported in Illinois, 1926–1949. (N, C, and S indicate respectively the Northern, Central, and Southern hunting zones in Illinois as shown in fig. 23.)

Year	Hunting Season for Rabbits	Average Date of First 10 Freezing Nights (27° F. or Less)			Days After Opening of Season to Mean Date of First 10 Freezing Nights (Average for Three Zones)	Tularemia Cases Reported November–February
		N. Zone	C. Zone	S. Zone		
1926...	Nov. 10–Jan. 31	Nov. 11	Nov. 17	Nov. 13	3.9	1
1927...	Nov. 10–Jan. 31	Nov. 14	Nov. 25	Nov. 24	11.5	11
1928...	Nov. 10–Jan. 31	Nov. 17	Dec. 4	Dec. 1	17.5	9
1929...	Nov. 10–Jan. 31	Nov. 15	Nov. 26	Nov. 23	11.7	63
1930...	Oct. 1–Jan. 10	Oct. 27	Nov. 9	Nov. 16	38.5	149
1931...	Nov. 10–Jan. 31	Nov. 26	Dec. 23	Dec. 9	29.9	96
1932...	Nov. 10–Jan. 31	Nov. 2	Nov. 16	Nov. 19	2.7	141
1933...	Nov. 10–Jan. 31	Oct. 30	Nov. 14	Nov. 25	3.0	144
1934...	Nov. 10–Jan. 31	Nov. 16	Dec. 9	Nov. 25	16.9	117
1935...	(N) Nov. 10–Jan. 31 (C) Nov. 20–Jan. 31 (S) Nov. 25–Jan. 31	Nov. 4	Nov. 25	Nov. 22	−1.2	34
1936...	(N) Nov. 10–Jan. 31 (C) Nov. 20–Jan. 31 (S) Nov. 25–Jan. 31	Nov. 3	Nov. 23	Nov. 17	−3.5	103
1937...	Nov. 10–Dec. 31	Oct. 27	Nov. 22	Nov. 10	−0.4	64
1938...	Nov. 10–Dec. 31	Nov. 17	Dec. 1	Nov. 22	13.8	500
1939...	Nov. 10–Jan. 15	Nov. 10	Dec. 12	Nov. 14	12.7	451
1940...	Nov. 10–Jan. 15	Nov. 9	Nov. 19	Nov. 18	6.2	164
1941...	Nov. 10–Jan. 15	Nov. 18	Dec. 5	Nov. 27	16.9	70
1942...	Nov. 10–Jan. 15	Oct. 23	Nov. 27	Nov. 14	1.6	40
1943...	Nov. 11–Jan. 31	Nov. 9	Nov. 24	Nov. 20	7.5	24
1944...	Nov. 11–Jan. 31	Nov. 5	Dec. 6	Dec. 8	15.7	132
1945...	Nov. 11–Jan. 31	Nov. 9	Nov. 22	Nov. 29	9.9	60
1946...	Nov. 11–Jan. 31	Nov. 21	Dec. 5	Dec. 3	19.1	121
1947...	Nov. 11–Jan. 31	Nov. 12	Nov. 25	Nov. 29	11.6	35
1948...	Nov. 11–Jan. 31	Nov. 12	Nov. 18	Dec. 8	12.1	41
1949...	Nov. 11–Jan. 15	Nov. 9	Dec. 3	Nov. 29	13.2	58

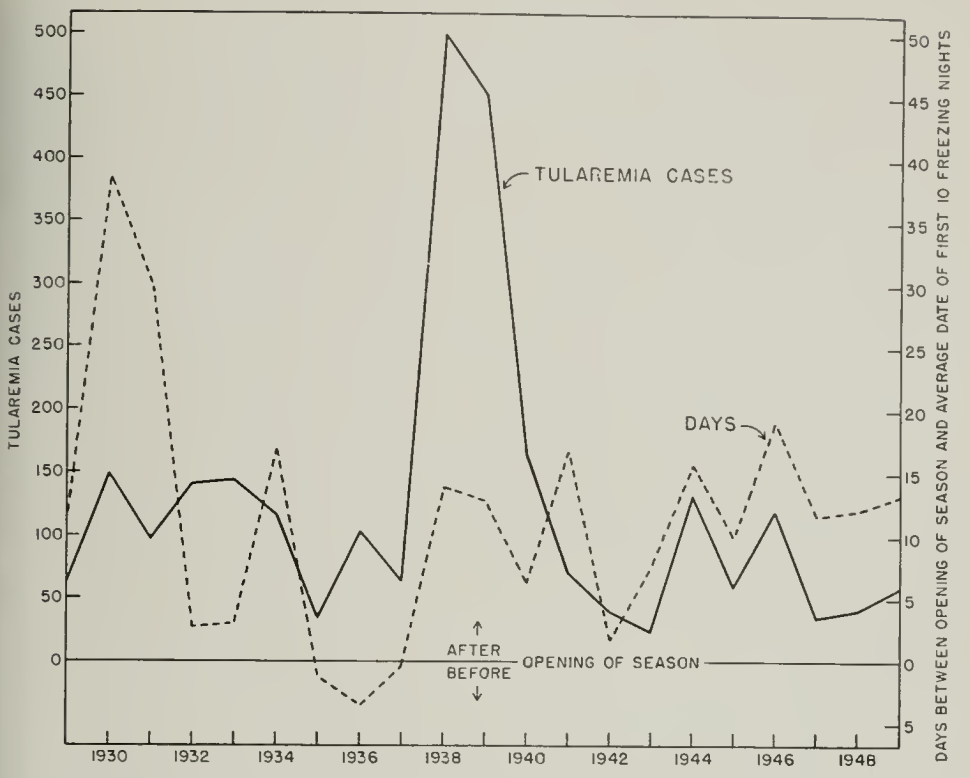


Fig. 24.—The number of cases of human tularemia per year in Illinois and the average date of the first 10 freezing nights in each autumn, 1929–1949.

remia rates in each of the three zones in each of those 5 years as they are related to the number of days between the opening date of the rabbit-hunting season and the mean date of the first 10 freezing nights. This 5-year period includes 1938 and 1939, when there was an epidemic of tularemia in Illinois, and 1936, 1937, and 1940, when the tularemia rate was about average. A summary is given in table 7.

Ecke's (1948) studies of ectoparasites on cottontails collected in central Illinois in the autumn of 1947 indicate that migration of rabbit ticks to hibernating places was at a peak in late October of that year and that the great majority of these ticks had left the rabbits to go into hibernation by the time of opening of the hunting season in early November. Temperatures were slightly above average in October and

Table 7.—Days from opening of rabbit-hunting season to average or mean date of first 10 freezing nights in autumn, number of hunting-zone-years represented, and tularemia rate in Illinois, 1936–1940. Figures on weather and human tularemia rate were obtained by averaging data for each zone separately.

Days From Opening of Rabbit-Hunting Season to Mean Date of First 10 Freezing Nights	Number of Zone-Years Averaged	Tularemia Rate, Cases per 100,000, November–February
30 to 39 days before	1	14 1
20 to 29 days before	1	14 2
10 to 19 days before	2	11.1
0 to 9 days before	7	4 3
0 to 9 days after	3	1 0
10 to 19 days after	1	0.4

November of that year. It seems probable that even though tick hibernation in central Illinois is usually well advanced by November 11, the opening date of the rabbit-hunting season in recent years, it is not complete. It is apparent that this date is too early to afford hunters the desired freedom from the danger of infection. Hibernation of ticks may be delayed by recurrence or persistence of warm weather; presumably it occurs somewhat later in southern Illinois, where the majority of tularemia cases are found, than in the central and northern parts of the state.

Portman (1944) reported finding rabbit ticks feeding on cottontails in the southern counties of Missouri during the winters of 1943 and 1944. He believed that southern Missouri is the approximate northern limit of the rabbit tick's year-round activity. Since the extreme southern counties of Illinois are close to and in approximately the same latitude as the Missouri areas where Portman did his collecting, it is possible that a certain amount of year-round activity of ticks occurs there also.

Although a fair number of Illinois hunters now delay their rabbit hunting until cold weather, apparently a great many still begin to take rabbits as soon as the season opens, believing that the animals will soon be thinned out and made wary by other hunters. The initial rush greatly emphasizes the importance of the date of opening of the season because this is the critical period for tularemia. No statistics are available in Illinois showing how much hunting is concentrated in the early days of the season, but we estimate that between one-third and one-half of the year's crop is taken in the first week.

In Ohio, Benjamin (1940) reported the daily kill of rabbits in the season of 1939 on 180,000 acres of state-supervised hunting areas scattered through 35 counties. A quarter of the season's total was killed on the opening day (November 8), and by the end of the fourth day (November 11) more than half had been killed. Incidentally, he found that the average daily kill per hunter was about twice as great on the opening day as it was 3 or 4 weeks later.

Burroughs & Dayton (1941) reported the daily kill of cottontails on 9,000 acres in Saginaw County, Michigan, in 1938 and 1939. In both seasons combined, more than a third of the annual kill was made on the opening day and more than a half by the end of the first week.

All available evidence indicates that an early rabbit-hunting season, such as is now in effect in Illinois, results in the handling by hunters of approximately half of the rabbit kill at a time when the possibility of contracting the disease is still comparatively great.

Although it is apparent that temperatures just preceding the opening of the rabbit-hunting season play an important part in determining the amount of human tularemia in Illinois, the influence of weather, as has already been suggested, is frequently modified by another factor, the abundance of rabbits.

Rabbit Populations and Tularemia

The tularemia rate for the whole Central Region of the United States, fig. 6, increased from 9.8 cases per million inhabitants in 1937 to 27.3 cases per million in 1938 and 28.1 cases per million in 1939. The sharp rise in the tularemia rate during the period 1937–1939 occurred simultaneously with a marked increase in the numbers of cottontail rabbits in the Central Region, especially in the middle Mississippi and the lower Missouri river basins. Subsequently, following a general decrease of rabbits, the tularemia rate declined, and, by 1942, only 6.1 cases per million were reported in that region. This apparent relationship between the prevalence of tularemia and the high peak of rabbit populations emphasized the need for further information on the behavior of game populations.

Studies of animal populations in recent years have shown that many kinds of animals are subject to more or less regular variations in numbers. The snowshoe or varying hare, *Lepus americanus* Erxleben, is often cited as a classic example of an animal that undergoes cyclic fluctuations. MacLulich (1937) concluded from an analysis of population data, including records of the Hudson's Bay Company covering more than a century, that the cycles of the snowshoe hare in Canada have varied in length from 8 to 11 years and have averaged 9.6 years.

Although long-time population records,

such as have been used in studies of the snowshoe hare, are lacking for cottontail rabbits, records obtained by workers in several northern states indicate that cottontail populations tend to fluctuate rather widely. This paper does not attempt to arrive at final conclusions as to whether Illinois cottontail rabbits have cyclic, and thus possibly predictable, fluctuations. Nevertheless, it seems advisable to discuss briefly the available records of cottontail population trends in Illinois and nearby regions in recent years, because of the apparent relationship of the populations to the incidence of human tularemia.

Fig. 25 shows the annual kill of cottontails in Wisconsin during the period 1931–1949 as computed from hunters' reports to the Wisconsin Conservation Department (Anonymous 1949 and personal communication from W. E. Scott). Cottontail rabbits occur throughout Wisconsin except possibly in a narrow zone along the northern border, but they are generally most common in the southeastern counties (Morgan 1949). The curve in fig. 25 probably reflects the trend of the total Wisconsin cottontail rabbit population during the period 1931–1949. The trend of cottontail populations appears to have followed rather closely the trends of snowshoe hare and grouse populations in Wisconsin during the same period, as shown by Grange (1948).

Although the Illinois cottontail rabbit population data are not so nearly complete as the data for Wisconsin, records from the Natural History Survey and other sources have made possible a partial reconstruction of the fluctuations of cottontail rabbit populations in the state during 25 recent years. These data include, in addition to field notes and published records, replies of sportsmen to questionnaires, estimates of rabbit populations in southern Illinois by the United States Forest Service, information received annually by the Natural History Survey on rabbit damage to crops and orchards, and bag records and field notes of qualified hunter-observers. Because these data refer to different regions, they show something of the local aspects of population fluctuations in Illinois. As already indicated, local fluctuations are important in considering the relation of rabbit abundance to human tularemia rates.

The most noteworthy feature of the behavior of Illinois cottontail rabbit populations during the quarter century was the sharp increase in numbers during the late 1930's, culminating in 1938 and 1939 in the highest populations in many decades. The increase of rabbits in Illinois was most evident in the southern half of the state, where the main endemic centers of tularemia are found. As has been mentioned, nearly 1,000 cases of human tularemia were reported in Illinois during 1938 and 1939. Unusually high rabbit populations during these years were reported also in Iowa, Missouri, Kansas, Arkansas, and some other central states, where the tularemia rate also showed a sharp rise. Dur-

Table 8.—Number of rabbits flushed per square mile during pre-hunting-season gamebird censuses on the Jasper County, Illinois, study area, 4 square miles, 1936–1941.

YEAR	NUMBER OF RABBITS PER SQUARE MILE
1936	4 5
1937	3.8
1938	11 2
1939	14 2
1940	8 5
1941	3.3

Table 9.—Number of rabbits flushed per square mile during pre-hunting-season censuses made by the United States Forest Service on sample areas of the Shawnee National Forest, in southern Illinois, 1935–1949.

YEAR	NUMBER OF RABBITS PER SQUARE MILE
1935	54 5
1936	50 8
1937	64 6
1938	89.8
1939	82.3
1940	87.8
1941	77.4
1942	—
1943	—
1944	—
1945	159 6
1946	69 4
1947	79 0
1948	54 3
1949*	54 3

*The United States Forest Service discontinued its censuses after 1948. Its wildlife report for the North Central states in 1949 stated that rabbit populations on the Shawnee National Forest were unchanged from 1948 to 1949.

ing 1938 and 1939, counts of rabbits killed on highways in southern Illinois were approximately six times as high as they had been in immediately preceding years. Table 8, showing numbers of rabbits flushed during game-bird censuses made by the Illinois Natural History Survey on a 4-square-mile study area in Jasper County in southeastern Illinois, indicates the trend of rabbit populations there during the period 1936–1941.

Table 9 shows estimates of the number of rabbits per square mile in the Shawnee National Forest in extreme southern Illinois during the period 1935–1949; the estimates are based on counts made by the United States Forest Service on sample areas of the different forest types. No censusing was done during 1942–1944. The Forest Service data indicate that the trend of rabbit populations in southern Illinois was in many respects similar to the trend in central Illinois, fig. 26, but some differences are apparent. For example, rabbit populations were high in both central and southern Illinois about 1939 and 1945, but, in the central counties, the population peak of the mid-1940's was considerably smaller than that of 1939, fig. 26. Also, rabbit numbers in central Illinois increased in 1948 and 1949, while in the Shawnee National Forest they apparently remained low.

Population records for the dark soil prairie region of east central Illinois cover a longer period of years than those for any other section of the state. Fig. 26 indicates the population trend during the years 1925–1949. The curve is based on highway "kill" records in central and east central Illinois for several years, morning roadside counts of live rabbits in and near Champaign County, 1942–1949, and bag records and field notes since 1925 of Joe L. Mote of Watseka, Illinois.

Mr. Mote is a veteran hunter and a competent observer of wildlife. His rabbit-kill data are particularly valuable because they cover a longer period than do any other known Illinois records. For years when he was unable to hunt, his notes give information on the abundance of rabbits. Although his records are from a single locality in east central Illinois, the indicated fluctuations of rabbit populations agree quite closely with those shown by the records we have from other parts of central Illinois.

Rabbit populations are usually not exceptionally high in the dark soil prairie of central Illinois, and fluctuations are less pronounced there than in the southern counties. Nevertheless, it was observed during 15 recent years that general trends of rabbit populations in the central counties approximated those in the gray soil prairie of south central Illinois, where the cottontail rabbit populations were relatively high and where human tularemia was most prevalent.

As fig. 26 indicates, in recent years rabbit populations in central Illinois have shown major increases at intervals of about 10 years, with minor fluctuations between. It is of interest that in recent years population peaks of the prairie meadow mouse, *Microtus ochrogaster* (Wagner), in central Illinois have occurred there at approximately the same times as those of cottontail rabbits. Mohr (1947) mentions meadow-mouse highs in the winters of 1939–40, 1942–43, and 1945–46. According to an annual report by G. C. Oderkirk of the United States Fish and Wildlife Service, prairie meadow mice were exceedingly abundant in western and northern Illinois in the winter of 1946–47. In the autumn of 1949, members of the Natural History Survey staff found a recurrence of high meadow-mouse populations in the dark soil prairie of central and north central Illinois. Grange (1949) states, "Everything points to the fact, then, that Illinois Cottontails are geared to the Mouse cycle, and the cycle of Mouse-Rabbit predators." He does not discuss in detail the interrelationships of cottontail and mouse populations.

Field records indicate that, in Illinois, fluctuations of rabbit populations tend to be regional rather than state-wide. Differences in population trends frequently have been observed to be latitudinal. It may be noted by comparing figs. 25 and 26 that major population peaks in Wisconsin have not occurred during the same years as in central Illinois. Differences in the trends of cottontail populations probably account in large part for the previously mentioned differences in the trends of the tularemia rates in the Northern and Central regions of the United States.

Fig. 25.—The calculated kill of cottontail rabbits per year in Wisconsin, 1931–1949. The basic data for this graph are from the Wisconsin Conservation Department.

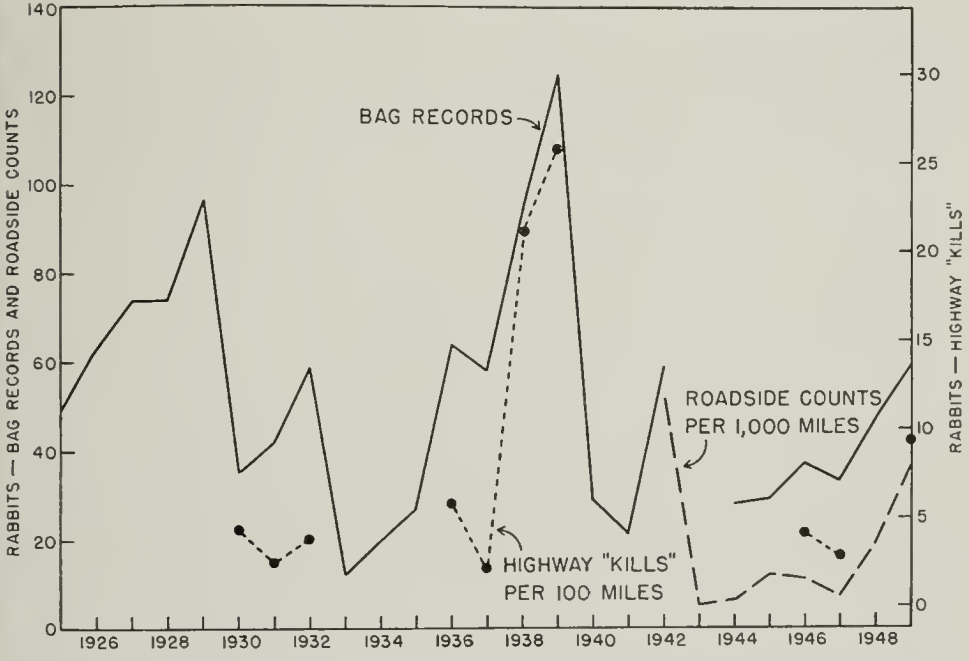


Fig. 26.—Cottontail rabbit population trends in central Illinois, 1925–1949, as indicated by bag records, highway "kill" counts, and roadside counts. Highway "kill" records for the years 1930–1932 are from Flint (1934) and for 1937 from Starrett (1938). The high rabbit populations of 1938 and 1939 were accompanied by a severe outbreak of human tularemia, fig. 24. Comparison of fig. 25 with fig. 26 indicates that major population peaks of rabbits did not occur in the same years in Wisconsin and central Illinois.

During periods of abnormally high rabbit populations, warm weather preceding the opening of the hunting season greatly increased the tularemia hazard in Illinois. In years when rabbit populations were unusually low, the tularemia rate remained low even during warm autumns, for example 1941, 1947, and 1948, fig. 24. When rabbit populations were average, the tularemia rate followed quite closely the curve of the mean date of the first 10 freezing autumn nights. Moderately high rabbit populations, such as occurred in the middle and late 1940's and probably in the early 1930's, brought increases in the number of human tularemia cases, but with these increases the disease did not reach epidemic proportions even during warm autumns.

Although there is evidence of more or less regular fluctuations in numbers of Illinois cottontails, our data do not indicate that many of these fluctuations are violent. The great population increase in 1938 and 1939 and the accompanying severe outbreak of human tularemia must be regarded as exceptional. Nevertheless, hunters should bear in mind that a sustained increase resulting in exceptionally high rabbit populations in their hunting areas may in turn favor a severe outbreak of tularemia among the rabbits.

At times, tularemia may be a factor that contributes to the decline of rabbit numbers following population peaks. Local tularemia outbreaks that were the apparent cause of reduction of cottontail populations from high to low levels have been reported by Waller (1940) and Hendrickson (1943) in Iowa, Hicks (1942) in Ohio, and others. It seems safe to assume, however, that tularemia is but one of numerous factors that contribute to population control among cottontails.

Tularemia and the Rabbit Hunter

Green (1942) has pointed out that tularemia is in large part a hunter's problem. This observation seems applicable to Illinois especially. At present, between 400,000 and 500,000 licensed sportsmen hunt annually in Illinois. In addition, many thousands of boys and men hunt on their home farms without being required to purchase hunting licenses. The great majority of these people confine their hunting entirely to upland game. Although many of the Illinois hunters now refuse to bag cottontails for fear of contracting tularemia, most of them depend largely on rabbit hunting for their sport.

The importance of the cottontail rabbit as a game species in Illinois will be evident when it is considered that rabbits can be found on virtually every square mile of farm land in the state and in most cities and towns, and that they are usually present in huntable numbers through the open season, even in intensively cultivated districts. All other resident game species tend to be local in distribution. Because cottontails can be found close to home by most Illinois hunters, which makes hunting them a relatively inexpensive recreation, and because they have desirable sporting and table qualities, these rabbits in recent years have averaged more than one-half of the number of game animals taken annually by the hunters of the state.

Cottontail rabbits have usually increased in numbers readily under wildlife habitat improvement programs that have been conducted in Illinois. This tendency was illustrated on the Urbana Township Wildlife Area by the marked rise of rabbit populations, noted by the senior author, that accompanied the growth of hedges and blocks of shrubs and trees during the years following planting on the area about 10 years ago. In favorable habitats, rabbits usually can be hunted heavily year after year without permanent reduction of their population levels (Pirnie 1949). In fact, heavy hunting may be a desirable game management measure to reduce temporarily the population levels of rabbits and thereby lessen the danger of epizootics.

It seems highly desirable for hunters in Illinois and other states where rabbits are important as game to have reliable information on how best to avoid contracting tularemia while hunting. The medical profession has recently made marked progress in successfully combating the disease in man. Wildlife research workers and game administrators in many states undoubtedly can contribute materially to the solution of the tularemia problem by determining hunting practices and hunting seasons likely to afford the greatest protection to hunters.

Green (1942) observed that tularemia in rabbits and hares in Minnesota was chiefly a spring and fall disease. He found infection to be relatively uncommon in these animals during the summer months and very rare during the winter. On the basis of the observed decline of tularemia in winter, he had previously (1935, 1939) urged delay of rabbit hunting until after the onset of cold weather.

In describing tularemia in rabbits, Green (1942) stated, "Tularemia is a bacterial disease; that is, it is caused by a microbe which can be seen under an ordinary microscope. The germ can be grown in the laboratory and is easily recognized by a trained bacteriologist. When this germ infects an animal, particularly a rabbit, it grows in the blood stream and in all the internal organs of the animal and produces the disease which we call tularemia.

"When an infected rabbit is encountered in the woods, its reactions are usually slow and the animal appears somewhat tame. Regardless of tularemia, it is always best to take only rabbits or other wild animals that show vigor and can be taken only with difficulty.

"The typical infection as found in a rabbit can be recognized by a peppering of tiny white spots on the liver and spleen. The white spots are abscesses caused by growth of the germ in those organs. The infection is of relatively short duration in rabbits and hares, usually lasting about seven days. Cottontail rabbits are very susceptible and always die; snowshoe hares are comparatively resistant and usually recover.

. . . . . .

"On cleaning a rabbit, if the reddish-brown liver or spleen is seen to be peppered with fine white spots, the carcass should be burned, one's hands should be repeatedly washed with soap and water and finally, if possible, with a disinfectant. Any cuts on the hands should be treated with iodine."

Inasmuch as other conditions than tularemia may cause spotting of the liver or other internal organs, figs. 27 and 28, this symptom is not conclusive evidence of the

Fig. 27.—Lesions of tularemia on liver and spleen of a domestic rabbit, following experimental infection. The small white spots become visible on the liver and spleen about the third day of illness. Photo by Nick Kramis, photographer, Rocky Mountain Laboratory, United States Public Health Service.

disease in rabbits. Fig. 27 illustrates the characteristic appearance of the liver and spleen of a rabbit infected with tularemia. Tapeworm cysts are found rather frequently in the muscles or attached to internal organs of Illinois cottontail rabbits. These cysts are not related to tularemia and are harmless unless eaten raw, but it is better to discard an affected rabbit rather than to try to cut out the cysts.

It should be borne in mind that rabbits and other game may not exhibit visible symptoms of tularemia in early stages of the disease. Francis (1937) stated of infected rabbits that "innumerable small round spots [on the liver] become plainly visible on the third or fourth day of illness, but these spots are too small to be seen on the first and second days of illness. Therefore, if a rabbit is shot on the first or second day of illness the liver, though diseased, will appear healthy." Because it is possible for infection to be present in apparently healthy animals, thorough cooking of all game is always a wise precaution. Tularemia contracted by humans as a result of eating infected game that is insufficiently cooked appears to be especially severe and is associated with a high death rate. Cooking of rabbits and other game until the bone marrow and the meat surrounding the bones are well done eliminates any danger of tularemia infection.

A number of organizations have advised hunters to wear rubber gloves when handling cottontails. Yeatter & Thompson (1943) have pointed out that this precaution, although probably offering a degree of protection, is not entirely practical and may give a false sense of security to hunters during tularemia epidemics. The hunter usually is bare handed when handling the gun, and during a day of hunting receives scratches from briers or barbed wire, or becomes chafed on the hands or wrists. In addition, as has been mentioned, considerable evidence indicates that infection can take place through the unbroken skin.

Although some hunters in recent years have put on cotton or leather gloves before picking up rabbits, they are probably in the minority. Every shot rabbit is smeared with blood, and, whether the animal is

Fig. 28.—Lesions of tularemia on lungs of a domestic rabbit, following experimental infection. Photo by Nick Kramis, photographer, Rocky Mountain Laboratory, United States Public Health Service.

carried in the hand or placed in a hunting coat, it may come in contact with the skin. Rubber gloves are not commonly used by hunters in the field, and, even though an attempt is made to use them while cleaning rabbits, there are several points of danger. The gloves may not be of sufficiently good quality, but, more important, the average hunter probably does not possess the training and skill required to use the gloves without puncturing them or to remove and sterilize them without contaminating the hands or face. Many laboratory technicians and medical workers have contracted tularemia even when all available facilities and known protective measures have been employed. Therefore, it is unlikely that rubber gloves alone offer the untrained layman much protection.

Although it would obviously be unwise to minimize tularemia as a hunting hazard, it should be pointed out that publicity given the disease by newspapers and radio has tended to instill in the public an exaggerated fear of becoming infected by handling wild rabbits during nonepidemic years or during late fall or winter months. The writers (Yeatter & Thompson 1943) have stated in this regard, "Tularemia is a serious disease and it is not our intention to underrate it, but it has been mostly a mental hazard since the peak years. The danger from car accidents and gun accidents, which is considerably greater, does not keep people from hunting. For example, in 1942, Illinois had 67 cases and one death from tularemia. In the same year Wisconsin, with almost the same number of licensed hunters had 109 gun accidents and 36 deaths. Comparable figures are not available for Illinois, but they are probably about the same as those for Wisconsin because 80 of the accidents and 24 of the deaths came during the small game season."

Hicks (1942), in recommending that the rabbit-hunting season in Ohio be delayed until December, pointed out that the delay in opening of the season would minimize the frequency of human tularemia and eliminate much of the psychological hazard which then detracted greatly from the pleasures of hunting in Ohio.

Hunters are not likely to follow elaborate precautions for handling rabbits skillfully enough to protect themselves from infection with tularemia. The writers believe that Illinois hunters can most effectively reduce the tularemia hazard to a minimum by delaying rabbit hunting until after the onset of sharp, freezing weather. This delay is urged especially for hunters in the Central and Southern zones of the state, where rabbit ticks presumably are active later in the fall than in the Northern Zone. It should be remembered that periods of exceptionally high rabbit populations, such as occurred in Illinois in 1938 and 1939, increase the danger of infection and call for special measures on the part of hunters.

Within the past decade, methods of treating tularemia in humans have been improved greatly, principally through the use of antibiotics. The United States Fish and Wildlife Service Wildlife Leaflet 271 (Anonymous 1948) stated in regard to the use of streptomycin in treating tularemia, "Many remarkable recoveries with few failures . . . . have been recorded following the use of this agent." Recently aureomycin and chloromycin have largely supplanted streptomycin in the treatment of tularemia. Probably the low death rate in Illinois in recent years, table 4, reflects the increasing use of antibiotics in treatment of the disease.

Recommendations

Detailed analysis of weather and tularemia records indicates that delaying the opening of the rabbit season until December is the most practical method for reducing tularemia in Illinois. Recommendation is therefore made that the opening date be changed to December 1 or, preferably, December 8, at least in the Central and Southern zones of the state. The opening date in the Northern Zone might, without serious hazard in most years, continue to be November 11. The gains to be expected from standpoints of public health and enjoyment of hunting seem to far outweigh any disadvantages that might arise from this proposed change in the game code. To compensate for the delay of the opening date, the rabbit season could be extended to January 30.

Because of its adaptability to farm habitats throughout Illinois, the cottontail rabbit is undoubtedly our most impor-

Fig. 29.—Illinois Natural History Survey entomologist examining wild cottontail rabbit for external parasites.

tant game animal. There are, however, a number of questions that need to be answered before the best use of this game animal can be made. Studies of population fluctuations should be continued, and records of long-time censuses on areas that are representative of the different sections of the state should be analyzed to give better methods for predicting population trends and possible disease outbreaks.

Studies should be made to supplement the investigations begun by Ecke (1948) for the Natural History Survey—studies involving the degree of infestation of rabbits by ticks and other tularemia vectors, fig. 29, the per cent of diseased animals, numbers of embryos per female, numbers of broods of young per female, weights, food, and other phases of the life cycle. The relation of tularemia and its vectors to rabbits, and to other wild and domestic animals, should be further examined.

It seems evident from tularemia studies already completed that much progress in controlling the disease can be made by enacting legislation for confining the hunting season to the colder months of the year, by educating hunters to take adequate safeguards, and by warning the public of any significant increases in the tularemia hazard. In event that exceptional conditions arise, such as those in 1938 and 1939, it is suggested that the Illinois Department of Public Health, the Illinois Department of Conservation, and the Illinois Natural History Survey, working

jointly, bring such an emergency to the attention of the governor of the state so that he may by proclamation defer the opening of the rabbit-hunting season until after the principal danger has passed.

Summary

1. An analysis of the human tularemia records of the United States Department of Public Health indicates that, on the basis of tularemia rates and seasonal incidence of the disease, the United States falls into four general regions, namely, Northern, Central, Southern, and Western.

2. In a 24-year period beginning in 1926, Illinois had about twice as many reported human tularemia cases as any other state. The great majority of these reported cases was among residents of the southern half of the state.

3. The high incidence of tularemia among hunters, their families, and others in southern Illinois appears to be related to the greater abundance of rabbits in that region.

4. The human tularemia rate in any year in Illinois seems to be determined both by temperatures about the time of the opening of the rabbit season and by the abundance of rabbits. Very high rabbit populations increase the tularemia hazard.

5. When rabbit populations were average, the human tularemia rates followed the curve of the mean or average date of the first 10 freezing autumn nights. When rabbit populations were low, the tularemia rates remained low, even during warm autumns. The most serious outbreak of human tularemia known in the past half century was in 1938 and 1939 when rabbit populations were exceedingly high and the autumns warm until well past the opening date of the season.

6. Delay in the opening of the rabbit-hunting season until December 1, particularly in the Central and Southern zones of Illinois, is recommended as the most practical management method for reducing the amount of human tularemia. The Northern Zone may, without serious hazard in most years, continue to open on November 11.

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