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Dermacentor Andersoni and Rocky Mountain spotted fever in national forest recreational sites of Utah

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DERMACENTOR ANDERSONI AND ROCKY MOUNTAIN SPOTTED FEVER IN NATIONAL FOREST RECREATIONAL SITES OF UTAH

A Thesis

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INTRODUCTION

Shortly after the turn of the century, the Rocky Mountain wood tick, *Dermacentor andersoni* Stiles, was recognized as the principal vector of Rocky Mountain spotted fever in western North America. Much human suffering and many deaths have resulted from this disease, and Utah is no exception. The presence of *D. andersoni* in the recreational sites of the foothills, canyons, and mountains of Utah offers a potential threat to the health of man. Expanding human population and increased use of recreational facilities enhances this potential.

The objectives of this study are to determine (1) the prevalence of adult ticks of *D. andersoni* at the recreational sites of Utah; and (2) the incidence of Rocky Mountain spotted fever rickettsia in the ticks of these areas. The study dealt only with adult ticks inasmuch as the immature stages do not attack man. Although the scope of this study was limited by a late spring, inclement weather during the early part of the study, and great travel distance, surveys were made of 91 representative recreational sites in the seven national forests of Utah.

REVIEW OF THE LITERATURE

Much information relative to the distribution, ecology, and biology of *Dermacentor andersoni* and its relationship to Rocky Mountain spotted fever has been published by scientists working on the control of the wood tick and spotted fever in western Montana and Canada. Although the literature is replete with such reports, only the major works and those related directly to this study are cited.

In 1892 Marx recognized the Rocky Mountain wood tick as a distinct species. In an unpublished manuscript, he referred to specimens taken from sheep in Texas as *Dermacentor venustus*. This name was first published when Neumann (1897) synonymized it with *Dermacentor reticulatus* of Europe. Stiles (1905) published the name *D. andersoni* for wood ticks from Montana, without including figures or a description. Banks (1908) described wood ticks collected in Washington, Colorado, Montana, Idaho, Utah, New Mexico and Texas, using Marx's manuscript name *D. venustus*. In this description he did not designate a type-specimen or mention any corresponding museum number. About a month later, Stiles (1908), believing the specimens from Montana to differ from those in Texas, described the Montana specimens as *D. andersoni* and designated the Texas specimens as *D. venustus*. In 1920 the case of *D. andersoni* versus *D. venustus* was submitted to the

International Commission of Zoological Nomenclature. Their decision, as set forth in Opinion 78, states that *D. venustus* dates from Marx in Neumann, 1897 and, therefore, has priority over *D. andersoni* Stiles, 1908 (Smithsonian Institution, 1924). At that time there was no definite provision in the Code covering names published in synonymies as was *D. venustus* Marx and *D. reticulatus*. Cooley (1938) examined all available type-specimens of *D. venustus* Marx, *D. venustus* Banks, and *D. andersoni* Stiles and found that all are definitely specimens of one and the same species. At this time Cooley chose to retain the name *D. andersoni* Stiles instead of returning to *D. venustus* Banks in an effort to avoid further confusion in the literature. In 1948 during the meetings of the XIIIth International Congress of Zoology at Paris, the International Commission of Zoological Nomenclature decided that the ruling given in Opinion 78 should be reviewed as soon as possible and that interested zoologists should be invited to present to the Commission their views on the action that should be taken in revising this opinion (International Commission of Zoological Nomenclature, 1950). Subsequently, Philip and Kohls (1961) petitioned the International Commission to suppress the name *D. venustus* and officially accept that of *D. andersoni* for the purposes of the Law of Priority, but not for those of the Law of Homonymy. In anticipation of an affirmative decision, the name *D. andersoni* Stiles is used in this study.

Dermacentor andersoni is known from northern New Mexico, northern Arizona, northeastern California, Nevada, Utah, western Colorado, western Nebraska, western South Dakota, southwestern North Dakota, Wyoming, Montana, Idaho, northeastern Oregon, eastern Washington, southern British Columbia, Alberta, and Saskatchewan (Hooker, 1909; Bishopp, 1911; Hunter and Bishopp, 1911; Cooley, 1938; Bishopp and Trembley, 1945; Gregson, 1956).

In Utah, Banks (1908) first recorded the wood tick from Bridger Basin (northeastern Utah). Hunter and Bishopp (1911) subsequently recorded it from the following counties: Box Elder, Cache, Iron, Uintah, Utah, and Wasatch. Edmunds (1948, 1951) added Davis, Duchesne, Emery, Garfield, Kane, Millard, Sanpete, Salt Lake, San Juan, Summit, Tooele, Washington, and Wayne counties to its distribution. Coffey (1953, 1954) extended the range to Daggett, Grand, Juab, Rich, and Sevier counties, and Beck (1955) listed the wood tick from all counties in Utah except Carbon. Other records in the Department of Zoology and Entomology of Brigham Young University show collections from Carbon County.

No specific studies and few notes on the elevational distribution of *D. andersoni* are found in the literature. Bishopp (1911) commented on the elevational range, and Bishopp and King (1913) noted the relationship between elevational distribution and seasonal occurrence in Colorado and Montana. In studies of Colorado tick fever in western

Montana, Bürgdorfer and Eklund (1959, 1960) recorded collections of *D. andersoni* from four different elevations. Notes on elevational distribution in Utah were given by Coffey (1953), Beck (1955), and Ho (1962).

Relative to the seasonal occurrence of *D. andersoni*, Cooley (1911) determined the length of the life cycle and the peak season for larvae, nymphs, and adults. Hunter and Bishopp (1911) and Bishopp and King (1913) noted the appearance of adults in the spring and their disappearance in the fall. Cooley (1932) published an extensive report on the seasonal history of the wood tick. Philip (1937) reported observations made over a period of six years on the seasonal occurrence of a tick population in western Montana. Gregson (1951) made an intensive study on the seasonal activity of the wood tick in Canada. Other publications containing data on seasonal activity are by Brown (1944), Bishopp and Trembley (1945), and Burgdorfer and Eklund (1959, 1960). Notes on seasonal occurrence in Utah were given by Coffey (1953) and Beck (1955).

Biotic conditions favorable to wood tick populations were discussed by Cooley (1911, 1932), Hunter and Bishopp (1911), Bishopp (1911), Parker (1918), Philip (1937), Brown (1944), Bishopp and Trembley (1945), and Gregson (1951, 1956). Cooley (1913) made observations on the specific habitat and habits of adults as they wait for passing hosts. Brown (1944) and Gregson (1951) described specific habitats in Canada which were especially favorable for tick populations. Studies dealing with abiotic factors such as temperature, air movement, precipitation, sun exposure, and time of day which affect tick activity were made by Bishopp and King (1913), Philip (1937), Mail (1942), and Brown (1944). Brief notes on some ecological factors affecting tick populations in Utah were reported by Coffey (1953), Beck (1955), and Ho (1962).

Rocky Mountain spotted fever was first recognized in western Montana in 1872 (Stiles, 1905). However, the causative agent of the disease was not discovered until 1919 when Wolbach named it *Dermacentroxenus rickettsii*. It is presently referred to as *Rickettsia rickettsii*.

Wilson and Chowning (1902) first suggested that *D. andersoni* was the vector of spotted fever. The first experimental evidence to support this hypothesis was obtained in 1905 by McCalla and Brenton in Idaho. Using a tick which had been removed from a person who had contracted spotted fever, a man and a woman were infected with a mild form of the disease from the bite of the tick (Ricketts, 1909). The results of this experiment were not published and were unknown to most scientists until after Ricketts (1906) and King (1906) simultaneously proved the wood tick to be the vector of spotted fever. Since this discovery numerous studies of potential vectors have been conducted, particularly in western Montana where the disease has been prevalent in a highly virulent form.

Rocky Mountain spotted fever occurs throughout the United States, southwestern Canada, and in areas of Mexico, Central America, and South America. Ticks of five other species have also been implicated with its transmission (Eklund, Stoenner, and Kohls, 1962). In Utah, spotted fever was first identified in 1905, and has affected man in every county (Beck, 1955). The highest incidence has been in areas where human populations are located near foothills and mountainous areas (Coffey, 1953).

The incidence of spotted fever throughout the United States as a whole decreased from 3.5 cases per million population to 1.2 per million from 1935 to 1963. The average fatality rate for all ages remained relatively constant over the years at 5.7%. In the Rocky Mountain region of the western United States, the incidence decreased from 45.8 per million to 2.7 per million from 1935 to 1963 (U. S. Department of Health, Education, and Welfare, 1965). In Utah the incidence and fatality rates for 10-year periods since 1925 are 19.9 per million with an 18.8% fatality rate (1925 through 1934), 24.4 per million with a 23% fatality rate (1935 through 1944), 12.5 per million with a 10.7% fatality rate (1945 through 1954), and 2.9 per million with no fatalities (1955 through 1964) (Utah State Department of Health, 1963).

The occurrence of spotted fever throughout the Rocky

Mountain region is closely correlated with the seasonal occurrence of *D. andersoni* and the outdoor activities of man in the spring. The greatest number of cases have occurred in April, May, and June, but at higher altitudes the danger season may extend farther into the summer (Parker, 1938; Hampton and Eubank, 1939; Larson, 1955). In Utah, Coffey (1953) noted that the earliest case was the first of April, the majority in June, and the latest case in November.

Studies dealing with the incidence of *R. rickettsii* in the wood tick were reported by Parker (1938), Gibbons (1939), and Bow and Brown (1945, 1952). The virulence of these rickettsia varies from a highly virulent to an avirulent immunity-producing strain. The virulence varies from one locality to another and from one season to another (Spencer and Parker, 1923; Parker, 1938; Price, 1953).

Even with the importance of this disease to man and its enzootic status in the western United States, much yet remains to be learned about its epidemiology and the ecology of its arthropod vectors.

METHODS AND TECHNIQUES

Study Areas

Ninety-one recreational sites in the seven national forests of Utah were selected for study. Selection was based on geographic location, automobile accessibility, elevation, size, and frequency of use as designated by the U. S. Department of Agriculture (1963). Table 1 lists the study areas in each national forest, and their locations are shown in Figure 1.

Field Methods

Recreational sites were visited from the first week in May until the latter part of August in 1964. An unusually late spring, inclement weather, and distance made it difficult to visit most areas more than once, although 30 were visited two or more times. Adult ticks were collected by dragging a four-foot by three-foot white flannel cloth slowly over the vegetation. Specimens adhering to the cloth were picked off, placed in vials containing sterile physiological saline, and transported to the laboratory in an ice cooler. Each collection was standardized by correlating the time spent flagging with the number of ticks collected. Consequently, relative populations are indicated on the basis of

Table 1. Recreational sites used as study areas in the seven national forests of Utah. (Refer to Figure 1 for specific geographic location.)

National forest and recreational site	Map ref. no.	Map coord-inate	Eleva-tion	Plant community
ASHLEY				
Aspen Grove	1	G-12	7,500	Aspen-Spruce
Carmel	2	E-5	6,500	Poplar-Spruce
Green Lakes	3	E-17	7,100	Ponderosa Pine
Greendale	3	E-17	7,000	Ponderosa Pine
Hades Canyon	1	G-12	7,700	Aspen-Spruce
Moon Lake	4	G-13	7,900	Lodgepole Pine-Aspen
Palisades	2	E-5	7,000	Poplar-Ponderosa Pine
Uintah Canyon	5	G-14	7,900	Ponderosa Pine-Aspen
Uintah River	5	G-14	8,000	Ponderosa Pine-Aspen
CACHE				
Friendship	1	B-9	6,000	Box Elder-Oak
Guinavah	2	B-9	5,400	Willow-Box Elder
Malibu	2	B-9	5,300	Willow-Box Elder
Monte Cristo	3	C-10	8,400	Fir-Aspen
Red Banks	4	A-9	6,500	Aspen-Willow
Spring	1	B-9	6,000	Box Elder-Oak
The Maples	5	D-8	6,200	Spruce-Fir
Wildcat	5	D-8	6,200	Spruce-Fir
Wood Camp	4	A-9	5,600	Box Elder-Willow
DIXIE				
Cedar Canyon	1	U-5	8,000	Spruce-Fir
Duck Creek	2	U-5	8,500	Aspen-Spruce-Fir
Navajo Lake	3	U-5	9,000	Spruce-Fir
Panguitch Lake	4	T-5	6,400	Ponderosa Pine
Pine Lake	5	T-8	7,800	Ponderosa Pine
Red Canyon	6	T-7	7,100	Ponderosa Pine-Juniper
Spruce	3	U-5	9,000	Spruce-Fir
Vermillion	7	T-5	6,600	Poplar-Spruce
FISH LAKE				
Bowery	1	P-9	8,800	Aspen
Buckskin Charley	2	N-7	6,100	

Table 1. (continued)

National forest and recreational site	Map ref. no.	Map coord-inate	Eleva-tion	Plant community
City Creek	3	R-7	7,600	Aspen-Poplar
Fish Creek	4	P-6	6,000	Poplar-Oak
Kents Lake	5	R-6	7,900	Ponderosa Pine-Oak
Mackinaw	1	P-9	8,800	Aspen
Maple Grove	6	N-7	6,400	Oak-Box Elder
Monrovian Park	7	P-8	6,300	Poplar-Oak
Oak Creek	8	M-7	5,900	Maple-Poplar
Ponderosa	5	R-6	7,000	Ponderosa Pine-Aspen
Shingle Mill	2	N-7	6,000	
Twin Creek	1	P-9	8,800	Spruce-Fir
MANTI-LASAL				
Ferron Canyon	1	N-11	7,000	Poplar-Ash
Ferron Reservoir	2	N-10	9,600	Spruce-Aspen
Forks of Huntington	3	L-11	7,600	Spruce-Fir
Gooseberry	4	K-10	8,400	Spruce-Aspen
Huntington Canyon	3	L-11	7,800	Spruce-Aspen
Lake Hill	5	M-10	8,500	Fir-Aspen
Manti Community	6	M-10	7,400	Evergreen-Aspen
Pinchot	7	N-9	7,000	Juniper-Oak
Twelve Mile	8	N-10	9,800	Spruce
Willow Lake	2	N-10	9,000	Spruce-Aspen
UINTAH				
Altamont	1	H-9	7,200	Aspen-Spruce
Aspen Grove	2	H-9	6,800	Aspen-Poplar-Evergreen
Balsam	3	T-10	6,000	Maple-Fir
Bear Canyon	4	K-9	6,800	Poplar
Bench	2	H-9	6,800	Aspen-Poplar-Evergreen
Chicken Creek	5	L-9	6,200	
Cottonwood	4	K-9	6,400	Poplar
Dip Vat	6	I-10	7,000	Spruce-Aspen
Granite Flat	7	G-9	6,800	Spruce-Poplar
Hawthorn	8	I-10	6,000	Willow
Hope	9	H-10	6,600	Box Elder-Oak
Little Mill	10	G-9	6,000	Box Elder-Poplar
Lodgepole	11	H-10	7,800	Lodgepole Pine-Aspen

Table 1. (continued)

National forest and recreational site	Map ref. no.	Map coord-inate	Eleva-tion	Plant community
Maple Canyon	12	L-9	6,800	Poplar-Oak
Mile Rock	10	G-9	6,400	Box Elder-Poplar
Mutual Dell	1	H-9	6,600	Spruce-Fir
Payson Lakes	13	J-9	8,000	Aspen
Pines	4	K-9	6,200	Ponderosa Pine-Poplar
Roadhouse	10	G-9	6,200	Box Elder-Poplar
Silver Lake Flat	7	G-9	7,400	Spruce-Fir
Summit	1	H-9	8,000	Aspen
Timpooneke	1	H-9	7,400	Spruce-Aspen
Tumbolt Park	14	J-9	6,200	Evergreen-Box Elder
Warnick	10	G-9	6,200	Box Elder-Poplar
Whiskey Springs	15	H-10	6,600	Box Elder-Poplar
Wolf Creek	16	H-11	9,600	Fir
WASATCH				
Beaver Creek	1	G-11	7,400	Lodgepole Pine-Aspen
Bountiful Peak	2	E-9	7,500	Evergreen-Aspen
Buckland Flat	3	E-9	6,900	Aspen-Oak
Clover Springs	4	F-9	6,900	Evergreen-Aspen
Fir Crest	4	F-9	6,800	Evergreen-Aspen
Hayden's Fork	5	F-12	9,000	Lodgepole Pine-Aspen
Main Boxelder	4	F-9	5,800	Box Elder-Oak
Mirror Lake	6	F-12	10,200	Spruce-Lodgepole Pine
Soapstone	7	G-12	8,000	Lodgepole Pine-Aspen
South Boxelder	4	F-9	5,700	Box Elder-Oak
Spruce	8	G-9	7,400	Spruce
Stillwater	9	E-12	8,500	Lodgepole Pine-Aspen
Sulphur	5	E-12	9,000	Spruce-Lodgepole Pine
Sunset	2	E-9	8,200	Oak
Tanner's Flat	10	G-9	7,100	Aspen
Terrace	4	F-9	6,200	Evergreen-Maple
Trial Lake	11	F-12	10,000	Spruce-Lodgepole Pine

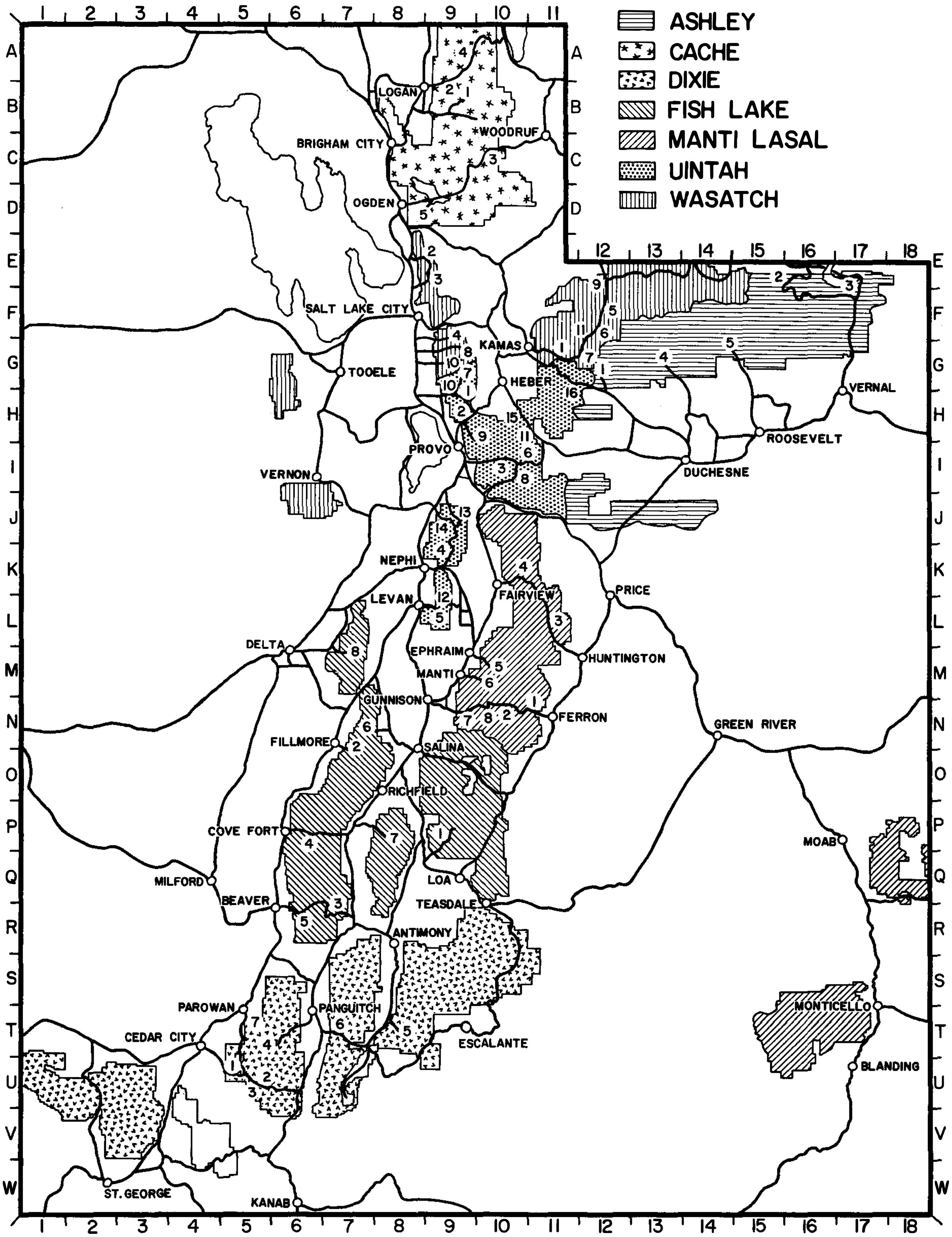

Fig. 1. Location of recreational sites used as study areas in the seven national forests of Utah.

numbers of specimens collected per hour. The habitat from which ticks were taken was classified as to plant type, size, cover, and age. Vegetation types were categorized as (1) grass, (2) grass and/or herbs, and (3) grass and/or herbs and short shrubs. The vegetation sizes were arbitrarily designated as (1) short, less than 6 inches, (2) medium, six to 12 inches, and (3) tall, 12 to 24 inches. Designations for the degree of vegetative cover were (1) scanty, less than 25% cover, (2) sparse, 25% to 50% cover, (3) medium thick, 50% to 75% cover, and (4) thick, 75% to 100% cover. The age of the vegetation was considered in the three categories of (1) young, (2) seed head stage, and (3) the drying or dry stage.

Laboratory Methods

In the laboratory, live specimens were identified to species, and several from each collection, males and females, were preserved in 70% ethyl alcohol for later reference. The others were rinsed several times in sterile physiological saline, males and females separated into pools (a maximum of 10 per pool), and stored in vials of sterile, non-fat skim milk at minus 30° C. Ticks were subsequently thawed, removed from the milk, and triturated with a sterile mortar and pestal. Sterile, non-fat skim milk was added to make a total volume of 10 ml. Guinea pigs were injected intraperitoneally with 1 ml of the supernatant. The remaining supernatant was stored in vials at minus 30° C for subsequent use in pathogen verification.

Every second day for 11 days following injections, observations of scrotal reactions of the pigs were made and rectal temperatures taken. When pigs showed an increase in temperature, measurements were taken for an additional four days. Those which died following injections were frozen and stored at minus 30° C. Later they were thawed and necropsied aseptically, and sections from the liver and spleen were streaked on Bacto-Cystine Heart Agar and Bacto-Civil Defense Agar plates which were incubated at 37° C for 48 hours. Gram stains were made of resulting bacterial colonies to differentiate between bacterial and rickettsial infections.

Twenty-eight days after initial inoculations 10 ml of blood were taken from each pig still alive. The serum was extracted and stored at minus 30° C for further testing. Four complement fixation screen tests were made on each sample. Serum for screen tests was diluted 1:16, then heated in a 60° C water bath for 30 minutes for inactivation of native complement. In the first and third tests a 1:30 antigen dilution (Lederle Laboratories Division, American Cyanimide Co.) was used, whereas in the second and fourth tests a 1:6 dilution was used. In each case 0.1 ml of antigen was added to 0.1 ml of the 1:16 serum dilution. Following this, 0.2 ml of two units of previously titrated complement was added. Anti-complementary test controls and a positive serum control were used. Mixed serum, antigen, and complement were refrigerated overnight.

The hemolytic system was prepared by mixing equal volumes of a two percent solution of red blood cells of sheep with two units of previously titrated hemolysin. To each of the serum samples, 0.2 ml of the hemolytic system was added, and the samples were incubated in a 37° C water bath for 30 minutes. Those not showing complete hemolysis were considered positive for spotted fever antibody.

Serum samples showing positive screen test results were retested and the antibody titer determined. Serial dilutions of serum from a 1:16 to a 1:512 dilution were made, then the tests were carried out as in the screen tests. In each case the first dilution showing 50% inhibition of hemolysis was considered to be the titer of the spotted fever antibody present.

As a final test, the surviving pigs were injected with a lethal dose of virulent Rickettsia rickettsii. Pigs not affected after 28 days were considered immune by having previously produced antibody against Rocky Mountain spotted fever as a result of the inoculation of triturated infected ticks.

RESULTS

Three hundred fifty-eight adult *D. andersoni* (135 males and 223 females) were collected in 115 attempts. The highest population was 60 per hour at Kents Lake in Fish Lake National Forest. The next highest were 52.5 at Manti Community in Manti-Lasal National Forest, and 52 several miles north of Payson Lakes in Uintah National Forest. Populations above 25 per hour were also observed in six other areas (Table 2). The average collection rate for all attempted collections was 6.8 per hour. When ticks were collected in high numbers they were generally found concentrated in small areas.

Distribution

The state was arbitrarily divided into three sections: (1) a south part consisting of the Dixie and Fish Lake National Forests; (2) a middle part consisting of the Manti-Lasal and Uintah National Forests; and (3) a north part consisting of the Ashley, Wasatch, and Cache National Forests (Figure 1). The average population densities in these sections were 12.2 per hour in the south section, 8.6 in the middle, and 1.6 in the north.

Highest populations were found between 6,500 and 7,500 feet elevation (Figure 2). No ticks were collected above

Table 2. Tick population density based on collection rates per hour for all collections. Areas where no ticks were found are omitted (see Table 1).

National forest and recreational site	Date	Population density		
		Males	Females	Total
ASHLEY				
Moon Lake	16 July	0	1.7	1.7
Uintah River	15 July	2	0	2
CACHE				
Friendship and Spring	7 July	4	4	8
Guinivah and Malibu	8 July	0	1.2	1.2
Wood Camp	8 July	3	0	3
DIXIE				
Cedar Canyon	3 June	4	8	12
Pine Lake	3 June	0	2.4	2.4
Red Canyon	3 June	3	3	6
Vermillion	3 June	12	24.3	46.3
FISH LAKE				
Bowery	4 June	2.2	2.2	4.4
Buckskin Charley and Shingle Mill	2 June	6	0	6
City Creek	2 June	24	21	45
	28 July	1.7	8.6	10.3
Fish Creek	2 June	4	16	20
Kents Lake	2 June	26	34	60
Mackinaw	4 June	0	1.7	1.7
Maple Grove	4 June	5.3	8	13.2
Monrovian Park	2 June	10.3	20.6	30.9
Oak Creek	2 June	0	7.5	7.5
Ponderosa	2 June	16.8	24	40.8
MANTI-LASAL				
Lake Hill	10 July	1.7	6.9	8.6
Manti Community	10 July	22.5	30	52.5
Pinchot	10 July	8	10	18

Table 2. (continued)

National forest and recreational site	Date	Population density		
		Males	Females	Total
UINTAH				
Altamont	25 June	6	12	18
Aspen Grove	25 June	3	7.5	10.5
	23 July	2.4	0	2.4
Balsam	6 May	2	0	2
	27 May	4.4	3.2	7.7
	23 July	0	1.7	1.7
Bear Canyon	28 May	0	2.2	2.2
Bench	25 June	0	12	12
Chicken Creek	4 June	4	0	4
Cottonwood	28 May	4.8	4.8	9.6
Granite Flat	26 May	5.3	9.3	14.7
	25 June	4.5	3	7.5
Hawthorn	27 May	3	9	12
Little Mill	26 May	1.3	5.3	6.6
Maple Canyon	10 July	4	4	8
Mile Rock and Warnick	3 July	4	0	4
Mutual Dell	25 June	8	12	20
North of Payson Lakes	28 May	26	26	52
Pines	6 May	4	0	4
	28 May	2.6	8	10.6
Silver Lake Flat	25 June	3	12	15
Timpooneke	25 June	8	22	30
	23 July	2	0	2
Tumbolt Park	10 July	4	4	8
Whiskey Springs	10 June	8	12	20
WASATCH				
Beaver Creek	14 July	0	8	8
Buckland Flat	16 June	0	10.5	10.5
Fir Crest and Clover Spring	8 July	3	0	3
Soapstone	22 August	0	1.7	1.7
Sunset	7 July	0	2.4	2.4
Tanner's Flat	12 June	2	2	4

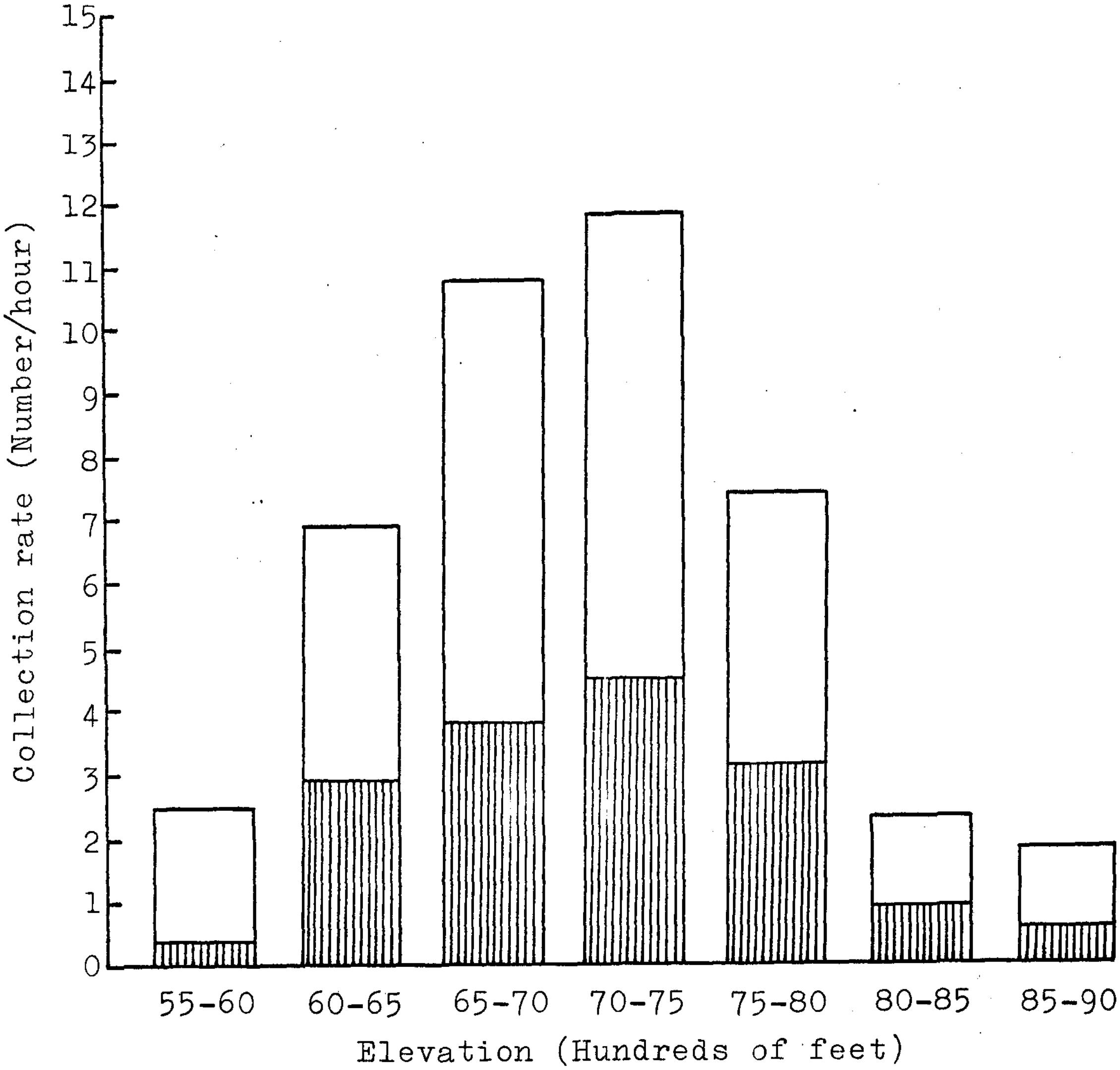

Fig. 2. Relative density of D. andersoni adults at various elevations. Lined columns represent males, unlined columns females.

8,800 feet. Greatest populations were found in higher areas in the southern sections of the state than in the northern (Figure 3).

Seasonal Occurrence

First attempts to collect ticks were made the first week in May, but inclement weather prevented further attempts until the fourth week in May. Relatively constant surveys were made for the remainder of the season. The peak period was between the fourth week in May and the end of June (Figure 4). Ticks collected the first week in May were predominately males, whereas females were more abundant the remainder of the season. Figure 5 compares the seasonal occurrence in the southern half of the state with that in the northern half. The relative populations were slightly greater at lower elevations early in the season and at higher elevations later in the season.

Biotic Factors Related to Population Density

The preferred habitat was open, unshaded areas of short, scanty, young grass (Figure 6). Ticks were most abundant in areas with a mixture of grass and herbs at higher elevations, and in grass at lower elevations. Population densities were greater in short vegetation at higher elevations and medium to tall vegetation at lower elevations. The same was evident for vegetative cover--greatest populations

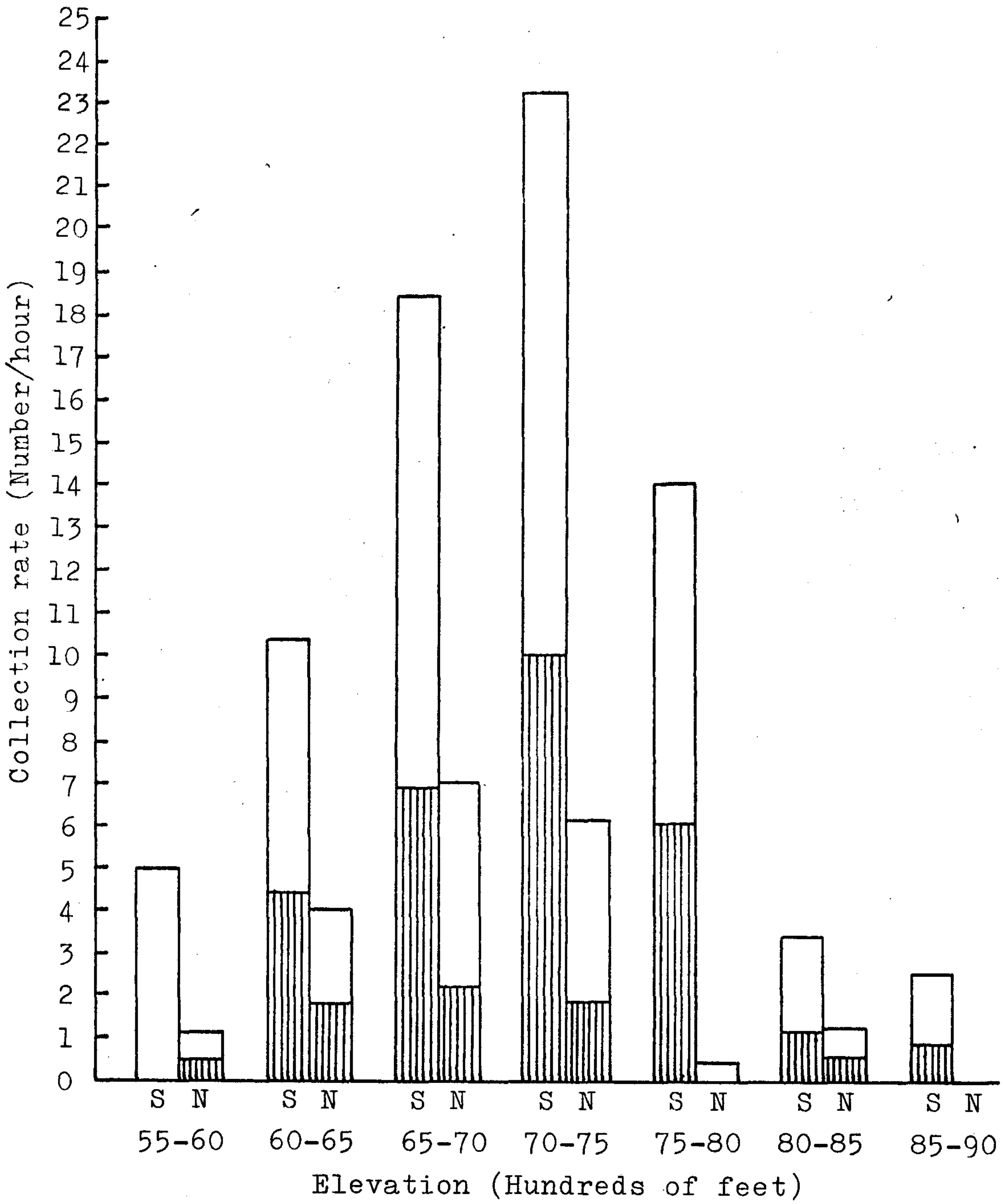

Fig. 3. Relative density of D. andersoni adults at various elevations in the southern (S) and northern (N) halves of Utah. Lined columns represent males, unlined columns females.

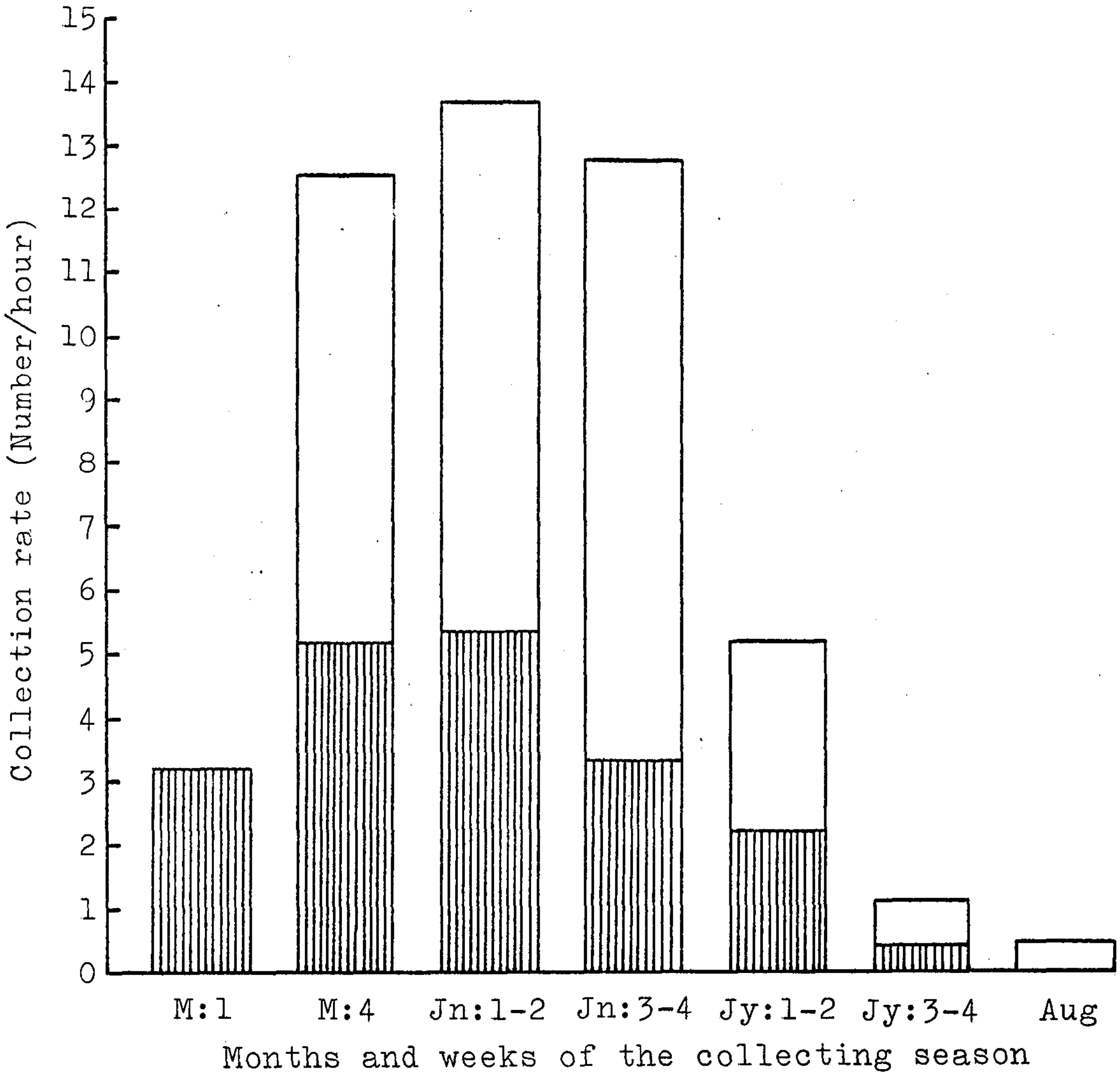

Fig. 4. Relative density of D. andersoni adults during May, June, July and August. Lined columns represent males, unlined columns females.

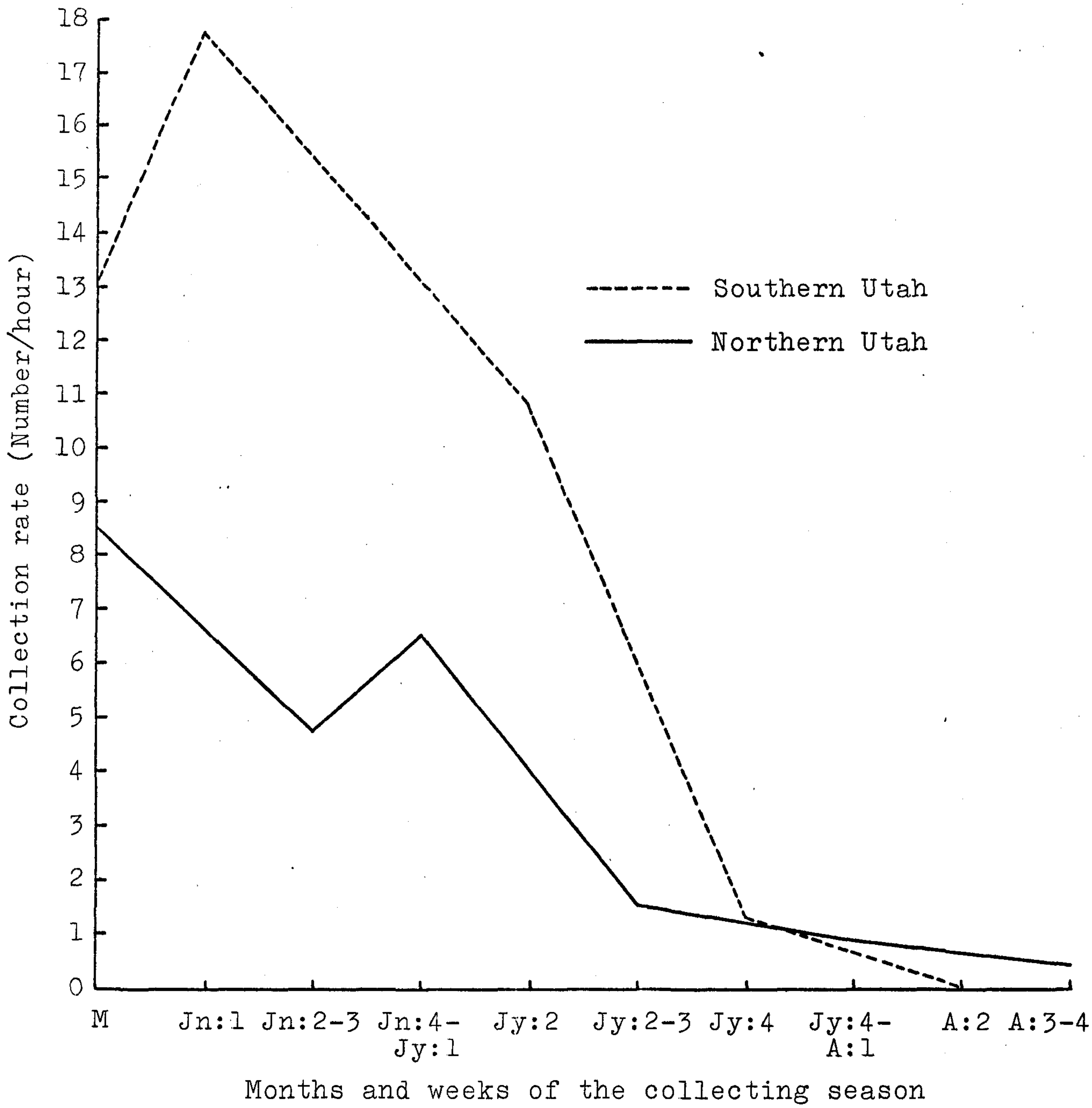

Fig. 5. Relative density of D. andersoni adults during May, June, July and August in the southern and northern halves of Utah.

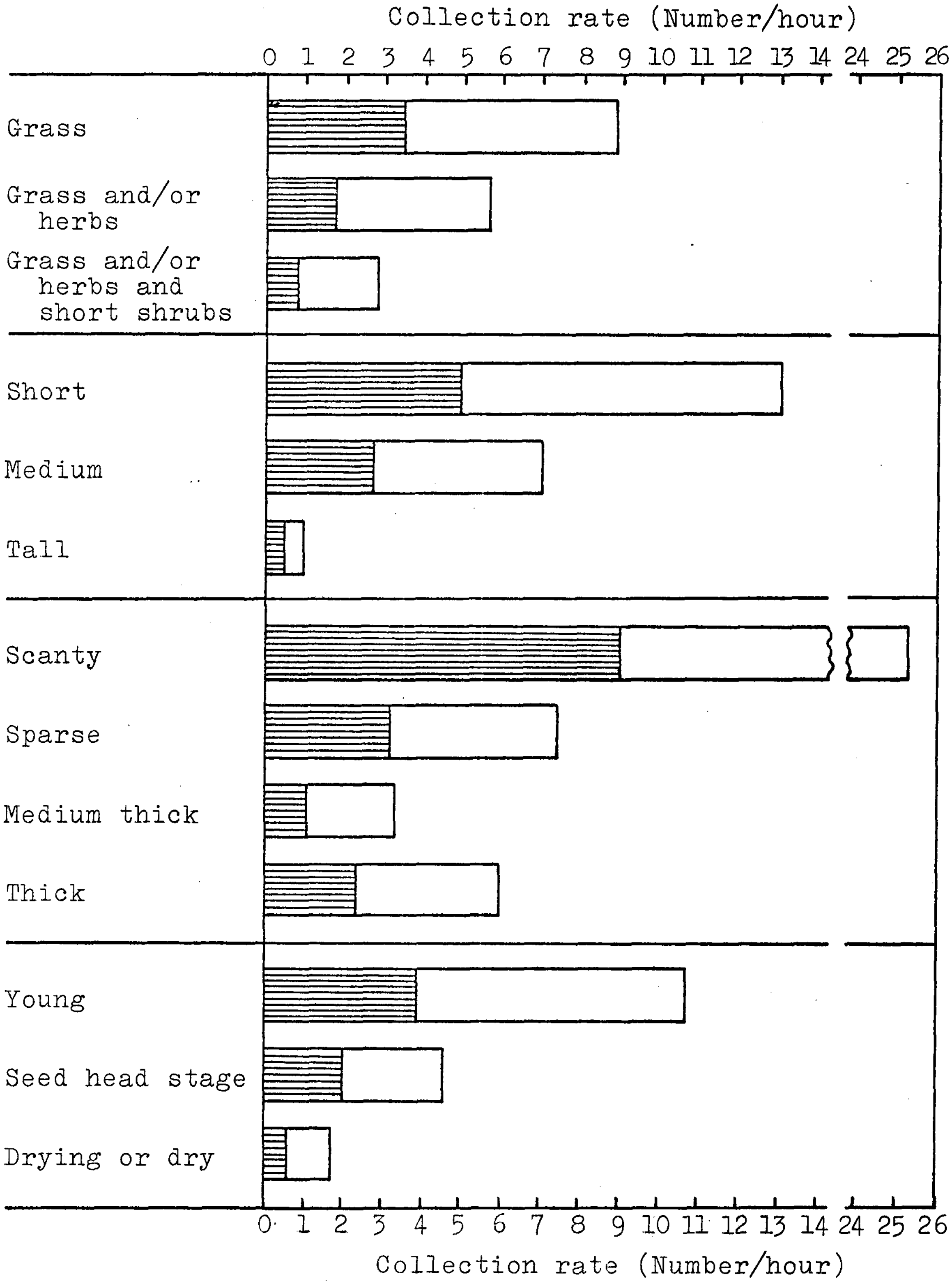

Fig. 6. Population density of *D. andersoni* adults relative to habitat. Lined columns represent males, unlined columns females.

were found in scanty to sparse vegetation at higher elevations, and in thick vegetation at lower elevations.

Abiotic Factors Related to Population Density and Activity

The activity of ticks increased gradually throughout the day to a high point in the late afternoon (Figure 7). The period of greatest activity between 6,000 and 7,000 feet elevation was 10 a.m. to 1 p.m.; between 7,000 and 8,000 feet, 4 p.m. to 7 p.m; and 8,000 to 9,000 feet, 10 a.m. to 1 p.m. No seasonal change in daily activity was evident.

Temperatures taken one foot from the ground at the time of each collection ranged from 12° to 38° C. There was no apparent optimum temperature range even though the population densities were slightly higher at some temperatures (Figure 8).

Tick activity was slightly greater on partly cloudy and cloudy days than on clear days, and activity increased proportionately relative to an increase in wind velocity (Figure 9).

Incidence of Rocky Mountain Spotted Fever

Table 3 lists the collections of D. andersoni adults where positive tests for Rocky Mountain spotted fever were demonstrated. Abnormal temperatures in guinea pigs resulted after injections of triturated tick material from 18 pools. Seven pigs showed abnormally high temperatures immediately

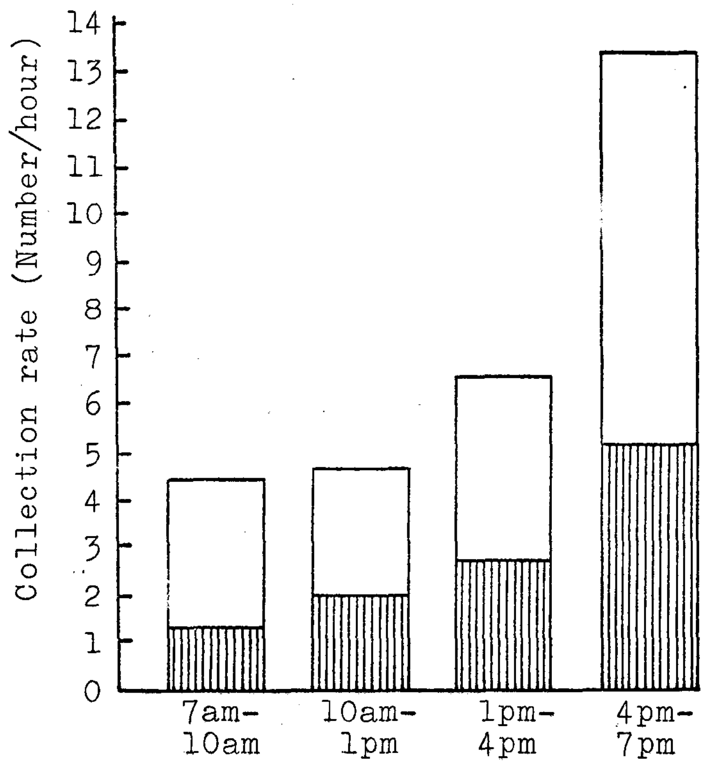

Fig. 7. Activity of D. andersoni adults relative to time of day. Lined columns represent males, unlined columns females.

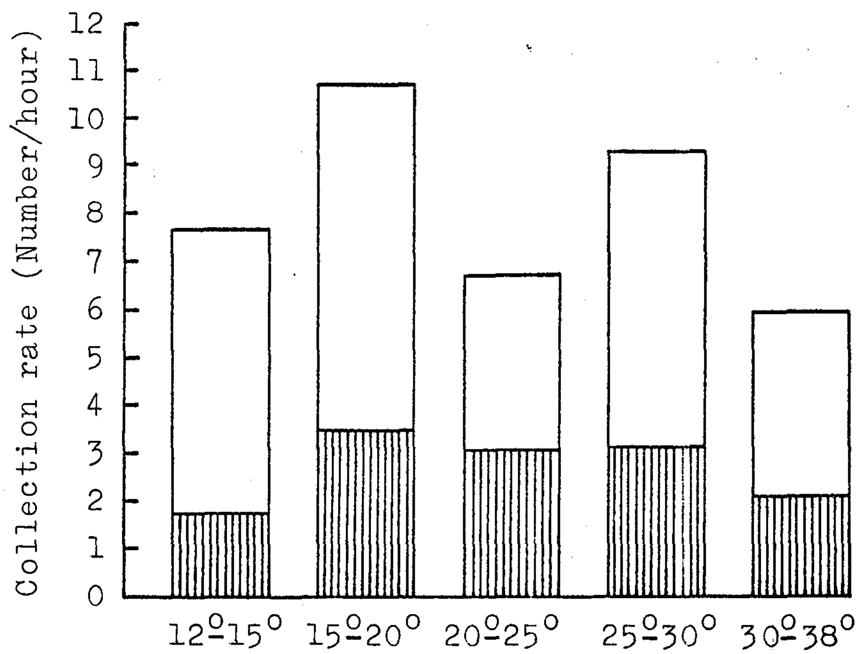

Fig. 8. Activity of D. andersoni adults relative to temperature range in degrees centigrade. Lined columns represent males, unlined columns females.

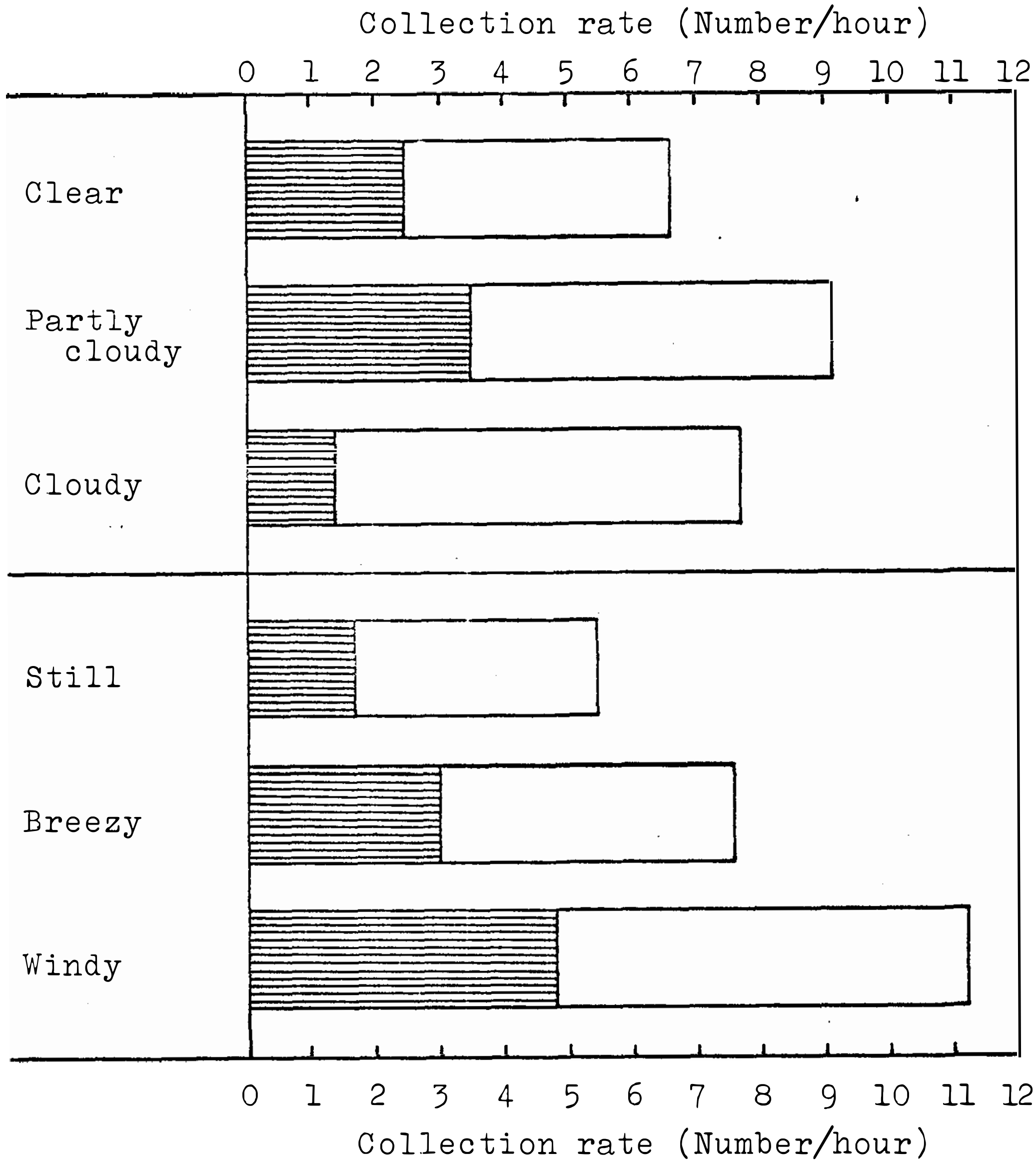

Fig. 9. Activity of D. *andersoni* adults relative to sun exposure and wind. Lined columns represent males, unlined columns females.

Table 3. Collections of *D. andersoni* adults wherein positive tests for Rocky Mountain spotted fever were demonstrated in at least one pool.

National forest and recreational site	Date	No. in pool	Results	Justification	
				C. F. test titer	Immunity** test
CACHE					
Friendship and Spring	7 July	2M, 2F*	+	32	+
FISH LAKE					
Bowery	4 June	2M, 2F	+	64	+
City Creek	2 June	8M	+	128	+
		7F	-	0	-
Monrovian Park	2 June	6M	+	128	+
		12F	-	0	-
Ponderosa	2 June	7M	-	0	-
		10F	+	128	+
MANTI-LASAL					
Manti Community	10 July	7M	+	128	+
		8M	-	0	-
		10F	-	0	-
		10F	-	0	-
UINTAH					
Altamont	25 June	2M, 4F	+	64	+
Aspen Grove	25 June	2M, 5F	+ ?	64	-
Mutual Dell	25 June	2M, 3F	+	128	+
Silver Lake Flat	25 June	1M, 4F	+ ?	64	-
Timpooneke	25 June	4M	+	128	+
		11F	-	0	-
Whiskey Springs	10 June	2M, 3F	+	128	+
WASATCH					
Sunset	7 July	1F	+	128	+

*M = males, F = females.

**+ = immune, - = susceptible.

after injection and throughout the observation period, whereas 11 had an increase in temperature after several days. None of the pigs demonstrated scrotal reactions. Eight pigs died within three to 14 days after inoculations, but necropsy indicated that their death was probably due to some bacterial infection.

Thirteen pools of ticks (21% of all pools tested) yielded positive complement fixation tests. Eleven of the 62 pigs challenged with virulent spotted fever organisms demonstrated immunity which indicated that they had produced antibody against spotted fever as a result of the prior inoculation of triturated tick material. These 11 correspond with 11 of the 13 pools of ticks yielding positive complement fixation tests. In two cases of positive tests the pigs were susceptible to the challenge. This close correlation between the results of the complement fixation tests and the immunity tests suggests that at least 11 and probably 13 tick pools were positive for spotted fever.

Four of the 13 pools of ticks considered positive for spotted fever were all males, two were all females, and seven were a mixture of each sex. These 13 pools represented 69 ticks--35 males and 34 females. If at least one tick in each of the positive pools were infected with spotted fever, then 3.6% of all the ticks collected were infected (at least 1.1% males, 0.55% females, and 1.95% mixed sexes).

The national forests from which the infected ticks were collected are: Cache, one infected tick pool; Fish Lake, four; Manti-Lasal, one; Uintah, six; and Wasatch one (Table 1 and Figure 1).

Three positives were found between 6,000 and 6,500 feet, three between 6,500 and 7,000 feet, five between 7,000 and 7,500 feet, one at 7,600 feet, and one at 8,800 feet.

The seasonal occurrences of the infected ticks were four during the first week of June from the Fish Lake National Forest; one the second week of June from the Uintah National Forest; five the fourth week of June from the Uintah National Forest; two the first week of July from the Wasatch and Cache National Forests; and one the second week of July from the Manti-Lasal National Forest.

DISCUSSION

Distribution

All the recreational sites from which *Dermacentor andersoni* adults were taken lie along the slopes of the Wasatch and Uintah Mountains, and in the Colorado Plateau country of southern Utah. Coffey (1953) noted a similar mountainous distribution for *D. andersoni*, but in other parts of the Great Basin this tick was uncommon.

The population density data presented in Table 2 indicate a considerable variation in tick populations at different sites. These variations probably are due to differences in the biotic and abiotic factors present at different sites. Latitudinally, population densities were greater in the middle and southern parts of Utah. Based on number of collections, Coffey (1953) and Beck (1955), however, showed the wood tick to be more abundant in the northern half of the state. Their records reveal that although almost twice as many adults were collected from the northern half than from the southern half of the state, the average number of specimens per collection was 4.0 in the northern half and 8.2 in the southern half. More collection attempts likely were made by them in northern than in southern areas; thus, more collections and consequently more ticks were recorded from northern Utah. Their records support the implications in this study that, where ticks are present, population densities are greater in the southern part of the state.

Coffey (1953) recorded collections from elevations ranging between 6,000 and 8,000 feet and noted the lack of ticks on animals at 9,000 feet. Beck (1955) noted an abundance of ticks from elevations of 5,500 to 7,000 feet in the mountains surrounding Cedar Valley in Utah County, and in another area in central Utah from elevations of 6,100 to 7,000 feet. Ho (1962) indicated that the wood tick is usually found at elevations above 6,000 feet. The elevational distribution observed in this study corresponds closely with that noted by these workers. In Utah the greatest wood tick populations are at elevations between 6,000 and 8,000 feet, and the upper limit is just under 9,000 feet. The lower limit is not known inasmuch as collections were made only as low as 5,500 feet in this study. Greater populations, however, were found at higher elevations in southern than in northern Utah. The optimum elevations were 7,000 to 7,500 feet in southern areas and 6,500 to 7,000 feet in northern areas. This latitudinal difference in elevational distribution is also suggested by several notations in the literature. Bishopp (1911) reported the elevational range of D. andersoni to be 500 to 9,000 feet, but reaching its greatest numbers between 3,000 and 5,000 feet. His report dealt primarily with studies conducted in western Montana. Bishopp and King

(1913) recorded the collection of ticks late in June at 7,200 feet in Colorado and at 5,500 to 6,500 feet early in July in western Montana. In their studies on Colorado tick fever in western Montana, Burgdorfer and Eklund (1959, 1960) collected wood ticks at elevations of 4,000, 5,000, 5,500, and 6,000 feet. In personal communication, Wilkinson (1964) stated that the Canada Department of Agriculture has records of collections from Banff, Alberta at over 4,500 feet. Thus, the elevational distribution of the wood tick likely varies with the latitudinal distribution. The optimum elevation becomes lower as one progresses from the southern limits of the range toward the northern limits. Further studies at selected sites dealing specifically with elevational distribution are needed to determine the lower and upper limits of the elevational distribution of the wood tick in relation to latitude.

Seasonal Occurrence

The earliest appearance of ticks in the spring was not determined, but the peak season was from the last week in May to the last of June. A sharp drop in activity occurred the first part of July, and the latest collection made was during the last week in August. Beck (1955) reported the earliest collections in Utah to be near the first of March with the peak season reached about the last week in April and the first week in May. Coffey's (1953) latest records were the first week in September. Analysis of other records in the Department of Zoology and Entomology at Brigham Young University showed the season to be from the first part of March to the first part of September with peak activity in May. Cooley (1932), Gregson (1951), and Beck (1955) indicated that the seasonal occurrence of tick populations in a given locality varies from year to year depending upon the current climatic conditions. In western Montana the first appearance of adults is normally about the middle of March (Bishopp and King, 1913; Cooley, 1932; Philip, 1937). Philip (1937) determined the peak season to be within the two weeks of April 11 to 25. He found that the populations decreased progressively thereafter with a sudden drop in June and an almost complete disappearance by mid-July. Bishopp and Trembley (1945) reported occasional collections as late as September and October. In Canada, Brown (1944) observed the season to extend from April to August with the peak abundance in May. In British Columbia, Gregson (1951) reported the earliest collections to be the last of February to the first week in March, and the period of peak abundance the last of March to the middle of April with a sudden disappearance by the last of May. The season of greatest activity is later in Utah than in Montana and Canada, and the season in Montana is later than in Canada. The late spring during this study likely is the cause for the unusual lateness of the peak season which was later in southern than in northern Utah. However further investigations into the seasonal activity at different latitudes are needed to determine the factors which influence such activity.

Seasonal activity early in the spring is correlated with the elevation. Tick populations were greater at lower elevations early in the season and at higher elevations later in the spring. Bishopp and King (1913) recorded the collection of a considerable number of ticks late in June in Colorado at 7,200 feet while finding none at 5,300 feet. They also noted a similar situation early in July in western Montana--ticks were numerous between 5,500 and 6,500 feet but few were found between 3,000 and 4,000 feet. Coffey (1953) observed this in his studies in Utah, as did Burgdorfer and Eklund (1959, 1960) in the studies in western Montana.

Throughout this study, except for the first few collections of the season, female ticks were more predominant than males. The overall sex ratio was two males to three females. Philip (1937) and Gregson (1951) noted that males are predominant early in the season and the females later, but with the overall sex ratio nearly equal. This unequal ratio of sexes in this study probably resulted from a lack of collections early in the season when the males were more abundant.

Biotic Factors Related to Population Density

Bishopp (1911) and Cooley (1911, 1932) indicated that the population densities of wood ticks are greatly influenced by the availability of two general classes of hosts--small mammals on which immature stages feed, and large wild and domestic mammals on which the adults feed. Parker (1918), Cooley (1932), Brown (1944), and Gregson (1951, 1956) found ticks in all types of country where the proper host animals were present. The types of hosts present were related to the type of vegetation available for sufficient food and cover. The type of vegetation in an area is dependent upon soil and climatic conditions, and other physical factors. Parker, Philip, Davis, and Cooley (1937) found the wood tick to be most abundant in localities where the vegetation was low and brushy with open areas. Gregson (1956) in Canada determined that the most favorable habitat was characterized by talus slopes backed by rocky bluffs where there was sufficient moisture to support vegetation.

Very little work has been done in Utah on the habitat of the wood tick. Beck (1955), Coffey (1953), and Ho (1962) listed hosts on which each of the stages feeds, and Coffey observed that tick populations were greater in areas where these hosts were most abundant. In this study ticks were most abundant in recreational sites having vegetation favorable for the host animals, and such sites likely contained high tick populations because of the availability of hosts. Wilkinson (1964) suggested that rodent hosts are probably more abundant in camp sites because of the refuse left by campers and picknickers. Such a concentration of hosts may account for the greater populations of ticks in these picnic areas. Ticks were concentrated in habitats where their rodent hosts spend time in search of suitable plant food. Some larger mammals such as cattle, deer, sheep, porcupines, jack-rabbits, etc., choose a similar habitat for foraging. Consequently the ticks may be concentrated in these areas which enhances their chances of obtaining a host. Cooley (1932) indicated that the reason ticks are very abundant in one spot and not in another is that nymphal ticks are dropped and molt in a particular spot, and the new adults remain in this spot to wait for a passing host. However, Cooley (1932) and Philip (1937) observed ticks to crawl "considerable" distances and become "moderately" concentrated along game trails and other areas where hosts are most likely to be encountered.

In this study the preferred habitats for ticks seeking a host were open areas of short, scanty, young grass. Cooley (1913, 1932) observed that adults ascended dead vegetation to await the passing of hosts, but indicated that they also will ascend living vegetation as well. Philip (1937) observed many ticks on dead grass and weed stems very early in the spring. However, it is doubtful that the ticks actually prefer dead over living vegetation. Ticks normally would be found on dead vegetation early in the spring before the new vegetative growth is tall enough to afford good waiting positions. Short, scanty grass which is the "preferred" vegetation type in the higher mountains likely is chosen because it is the most available type early in the season. The grass does not grow tall and thick until later in the season at the time when populations of ticks begin to decrease. Consequently, the size and age of the vegetation is only an indication of seasonal occurrence. The reason for a greater abundance of ticks on scanty to sparse, short grass and herbs at higher elevations and on thick, taller grass at lower elevations probably is that these types of vegetation are more characteristic of these respective elevations, and not that the habits of the ticks differ.

Abiotic Factors Related to Population Density and Activity

Philip (1937) and Brown (1944) noted that ticks were nearly as active at night as during the middle of the day. Brown suggested that ticks should be just as active during the night as the day because it is at night that the host animals are the most active, and the drop in temperature might produce increased activity. Moderate temperature changes apparently have little effect on tick activity. Although temperatures ranged from 12° to 38° C in the present study, tick activity increased from morning to late afternoon when the temperature began to decrease. Gregson (1951) failed to find any striking change in tick activity with fluctuations of temperature and humidity. He suggested that the disappearance of ticks later in the season is due to some form of diapause, the cause of which is unknown. Philip (1937) and Brown (1944) observed decreased tick activity during very hot, very cold, and stormy weather. They also noted that ticks did not seek shelter during adverse weather but remained in a more or less inactive state on the vegetation. Bishopp and King (1913) found that tick activity in the spring begins within six to 12 days from the time when the daily mean temperature ranges between 3° and 6° C for several consecutive days. They also suggested that dormancy is produced in the fall when temperatures range between 9° and 12° C. Mail (1942) determined the lethal temperatures for wood ticks to be -10° to -14° C at the lower range and 45° to 46.5° C at the higher range. He also observed that ticks from regions of colder climate and longer winters have a greater resistance to freezing than those from regions of warmer climate and shorter winters. If ticks in colder climates are more resistant to cold and less resistant to heat, it is expected that they would have an earlier season. This may partly explain why the seasonal occurrence in the northern ranges is earlier than in the southern ranges. There seems to be no temperature range at which ticks are at their maximum activity, and although the average mean temperature increases as the season progresses, this change apparently has little or no affect on tick activity. Differences in daily activity at different elevations and at different seasons probably are not significant.

Cooley (1913, 1932) observed that ticks were stimulated by an abrupt appearance of a shadow or change in light intensity, and suggested that ticks in nature are made aware of an animal by its shadow. In the present study tick activity was greater on partly cloudy to cloudy days than on clear occasions. As a cloud cuts off the sun light the ticks may be stimulated to activity in a manner similar to the shadow of an approaching animal.

Moderate wind or air movement increased tick activity, although increased activity could not be related to very strong, gusty winds because the flag was blown from the vegetation and collecting operations were hampered. Cooley (1913), in experimenting with ticks in a cage, observed that activity was increased by blowing the breath through the top of the cage. He further suggested that ticks may be informed of the presence of a host by feeling its breath. These observations indicate that ticks are stimulated to activity either by air movement or an increased amount of carbon dioxide in the immediate environment. Thus, on breezy and windy occasions ticks may be stimulated to greater activity by the movement of air and vegetation which may be interpreted as being caused by an approaching animal.

Incidence of Rocky Mountain Spotted Fever

Spencer and Parker (1923), Parker (1938), and Price

(1953, 1954) noted that the virulence of the rickettsia in ticks varies from one season to another and one locality to another where the disease is endemic. In ticks just emerging from hibernation they found the rickettsia to be inactive or in a phase which causes "inapparent" infection. The mechanisms for increasing the virulence to its maximum potential are the ingestion of a blood meal and/or exposure to a temperature of about 37° C. Price (1953, 1954) demonstrated four different strains of R. rickettsii in wood ticks in nature. He categorized them as R, S, T, and U depending upon their behavior in guinea pigs. Type R causes marked fever, scrotal swelling, necrosis, and death; type S causes mild fever, swelling of the scrotum without necrosis, but does not cause death; type T causes only fever; and type U does not cause any sign of disease but immunizes animals against subsequent challenge with the virulent types. Price (1954) indicated that areas containing high and/or low virulent strains exist in nature, and the virulence in each area and the ratio of high to low virulence remains relatively constant year after year.

In this study none of the pigs demonstrated scrotal reactions or necrosis, only three of the positive pigs showed abnormal temperatures, and only one died. The abnormal temperatures and deaths are attributed to something other than spotted fever because of the lack of correlation with those pigs which showed positive complement fixation and immunity tests. As indicated in Table 3, eleven pools of ticks gave positive complement fixation and immunity tests. Two others were questionable because they gave positive complement fixation but negative immunity tests. The complement fixation titers of these 13 pools ranged from 32 to 128 whereas the known positive control gave a titer of 512. This indicates that most if not all of the ticks shown to be positive for *R. rickettsii* probably were infected with the avirulent type U or type T strain. It is possible, however, that since these ticks had not ingested a blood meal the rickettsia may not have been reactivated, although those collected later in the season probably would have been exposed to environmental temperatures high enough to cause reactivation.

Parker (1938) indicated that the percentage of ticks infected with spotted fever rickettsia differs from one locality to another and from year to year in the same locality. He stated that the incidence in ticks is frequently less than one percent and rarely exceeds five percent, but in small localized areas has been found to be as high as 11%. Gibbons (1939) reported that in a survey in Canada, only one lot out of 29,545 wood ticks tested gave results suggestive of a low grade immunizing infection. Bow and Brown (1945, 1952) reported the number of ticks infected in nature to be near two percent. If at least one tick in each of the 13 positive pools in this study were infected, then 3.6% of all ticks collected were infected. This represents a minimum percentage of infected ticks because some of the rickettsia may have been lost by freezing the ticks. Also the immunological tests may have not detected spotted fever in ticks harboring only a very few rickettsia. Of these 13 pools four were all males, two were all females, and seven were of mixed sexes. For each of the four positive pools of males there was one or two pools of negative females from the same area. This same situation occurred with the two pools of positive females. In no collections where the sexes were in separate pools did both males and females test positive, and in no case did more than one pool from an area test positive. The infected ticks were from 13 of the 91 recreational sites visited, and eight of the 13 were from sites in the northern half of Utah near human population centers. Positive pools were found at every elevation range at which collections were made. Infected ticks were collected throughout the period from early June to the latter part of July.

Further studies relative to the incidence of _R. rickettsii_ in wood ticks with a determination of virulence would be helpful in determining the enzootic status of Rocky Mountain spotted fever in Utah. Such studies should include the technique of identifying _R. rickettsii_ in ticks by means of fluorescent antibody staining as described by Burgdorfer and Lackman (1960) and Shephard and Goldwasser (1960), as well as by guinea pig inoculations to determine the relative virulence.

SUMMARY

Three hundred fifty-eight adult *Dermacentor andersoni* (135 males and 223 females) were collected from 48 recreational sites during the spring and summer of 1964. The average collection rate (population density) for all collections was 6.8 per hour, but populations varied between sites. Populations were greater in the middle and southern parts of the state than in the northern. The greatest populations were at elevations between 6,000 and 8,000 feet with the upper limit just under 9,000 feet. The elevational distribution varied with the latitude--greater populations were found at higher elevations in southern than in northern Utah. The season of peak abundance was between the last week of May and the last of June. Populations were greater at lower elevations early in the season and at higher elevations later in the spring. Male ticks were more abundant early in the season whereas females predominated later. The preferred habitat was open, unshaded areas of short, scanty, young grass. Ticks were collected in greater numbers in the afternoon than in the morning. Temperatures between 12° to 38° C apparently had little effect on tick activity. Activity was slightly greater on partly cloudy and cloudy days than on clear days, and increased proportionately relative to an increase in wind velocity. Spotted fever rickettsia were found

in 3.6% of the ticks collected from 13 different recreational sites, over half of which are in the northern half of Utah near human population centers. Ticks positive for spotted fever were probably infected with avirulent type U or type T strain of *R. rickettsii*. Even with the present knowledge of Rocky Mountain spotted fever, much yet remains to be learned about its epidemiology and the ecology of its arthropod vectors.

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ABSTRACT

The objectives of this study were to determine (1) the prevalence of adult ticks of *Dermacentor andersoni* in national forest recreational sites of Utah, and (2) the incidence of spotted fever rickettsia, *Rickettsia rickettsii*, in the ticks of these areas. With the use of a white flannel cloth, 358 adult *D. andersoni* (135 males and 223 females) were collected from 48 recreational sites during the spring and summer of 1964. Ticks from each collection were put in pools, preserved in non-fat skim milk at -30° C, and subsequently tested for the presence of spotted fever rickettsia by guinea pig inoculations.

The average collection rate (population density) for all collections was 6.8 per hour, but populations varied between sites. Populations were greater in the middle and southern parts of the state than in the northern. The greatest populations were at elevations between 6,000 and 8,000 feet with the upper limit just under 9,000 feet. The elevational distribution varied with the latitude--greater populations were found at higher elevations in southern than in northern Utah.

The season of peak abundance was between the last week of May and the last of June. Populations were greater at lower elevations early in the season and at higher elevations

later. Male ticks were more abundant early in the spring whereas females predominated later.

The preferred habitat was open, unshaded areas of short, scanty, young grass. Ticks were collected in greater numbers in the afternoon than in the morning. Temperatures between 12^{o} and 38^{o} C apparently had little effect on tick activity. Activity was slightly greater on partly cloudy and cloudy days than on clear days, and increased proportionately relative to an increase in wind velocity.

Spotted fever rickettsia were found in 3.6% of the ticks collected. These were from 13 different recreational sites, over half of which are in the northern half of the state near human population centers. Ticks positive for spotted fever were probably infected with avirulent type U or type T strain of *R. rickettsii.*

Approved:

12 April 1966

Date