James Ray Coggins A SEASONAL STUDY OF PARASITE POPULATIONS IN THE COTTON RAT, SIGMODON HISPIDUS (SAY). (Under the direction of Dr. James S. McDaniel) Department of Biology, June 1972.

The seasonal dynamics of parasite populations in *Sigmodon hispidus* were evaluated. Cotton rats were collected each month during a two-year period (June 1970 through March 1972) in a grassy field in Greenville, North Carolina. Of 130 cotton rats autopsied, 114 (87.7%), were infected with one or more species of helminths. A total of 2,208 parasites representing two phyla and five species were recovered. These were *Raillietina bakeri*, *Hymenolepis diminuta*, larval *Taenia taeniaeformis*, *Mastophorus muris ascaroides*, and *Longistriata adunca*. Identification of the larval *T. taeniaeformis* was supported by the infection of a laboratory cat with stroblicerci from the liver of cotton rats and subsequent recovery of the adult worm.

A seasonal variation in incidence of infection with individual species of parasites was observed, with high infections in summer and winter and low in spring and fall for each species. Differences were observed in degree of infection between male and female hosts. Male cotton rats had greater infections than females for all species of helminths, although the differences were not statistically significant ($P < .05$) except for *L. adunca*. Spring is the time of heavy recruitment of parasites by the cotton rat host and seasonal variation in numbers of helminths may be related to the availability of intermediate and definitive hosts. High temperature and low rainfall in summer may

retard development of eggs or intermediate hosts, accounting for a decline in infection during fall. Behavior of the cotton rat may account for heavy infections with *L. adunca*, a parasite without an intermediate host. Age of the host appeared to be related to the number and kind of parasites present. Older rats had more and a greater variety of parasites than did younger rats. Pregnant female rats had infections similar to non-pregnant female rats. The effect of host diet, climate, daily temperature and rainfall differences were evaluated.

A SEASONAL STUDY OF PARASITE POPULATIONS IN THE COTTON RAT, *SIGMODON HISPIDUS* (SAY)

A Thesis

Presented to

the Faculty of the Department of Biology

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts in Biology

by

James Ray Coggins

June 1972

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ACKNOWLEDGMENT

I would like to express appreciation to my thesis advisor, Dr. James S. McDaniel, for his generous assistance and timely criticism, without which this thesis would not have been possible.

Dedicated to My Wife

Hilda Dianne Coggins

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INTRODUCTION

The parasites of the cotton rat, *Sigmodon hispidus*, have been extensively studied, due largely to the presence of a filaroid nematode, *Litomosoides carinii* (Travassos, 1911). This worm, which inhabits the pleural cavity, has been used in several research laboratories as an experimental animal (Thompson, Boches, and Blair, 1968; Hawking and Worms, 1967). Except for this one parasite most research on the parasites of *S. hispidus* has been limited to an enumeration and description of the organisms found. Protozoan parasites have been described for this animal (Culbertson, 1941; Petana, 1969), while lists of helminths from Texas and Maryland cotton rats have been published (Melvin and Chandler, 1950; Luttermoser, 1936). The list for Texas has since been extended by Schnell (1950) and Smith (1954). Harkema in 1936 published a monograph on parasites of some rodents in North Carolina. This work gives only slight attention to the cotton rat. Later work by Harkema and Kartman (1948) lists parasites of *S. hispidus* from two localities of the southeastern states, including piedmont (central) North Carolina.

The field of parasite population dynamics has not received the attention it deserves. Dogiel and other Russian workers have been instrumental in promoting this branch of research (Dogiel, 1961; 1964). Although mainly dealing with fish parasites, their work has yielded many principles concerning the relationship of parasitic fauna to the conditions of the host's life history, ecology, physiology, and biochemistry. Kennedy (1970) dealt with energy flow in a parasitic relationship, and is one of the few Western workers to consider the environment as a system. Harkema and Kartman (1948) mentioned a seasonal variation in total parasite load in the cotton rat. Layne (1969) dealt with seasonal variation of Capillaria hepatica in S. hispidus.

This thesis enumerates the parasites found in S. hispidus taken from a grass field in eastern North Carolina over a two-year period and will examine the relationship between individual parasites, each species of parasite, and the parasite-mix (Noble and Noble, 1971). Parameters considered were host sex, age, and condition, intermediate hosts, season of the year, and temperature.

It is still important to know the parasites harbored by common domestic and wild animals since such animals may be economically important or share their parasites with man. Hopefully through this work certain principles will emerge that will guide others in exploring this field and will aid in understanding the phenomenon of parasitism and ecology of parasites.

The rodent host, S. hispidus (family Cricetidae), inhabits dense grassy areas, fields and roadsides overgrown with broomsedge and weeds, and waste borders of cultivated fields. The nests are built of dry grass, plant debris, and other available material and are located under logs, rocks, or at the end of shallow tunnels. The cotton rat is mainly a nocturnal animal that prowls winding runways within the home range, an area of about one acre for males and one-half acre for females.

They seldom live more than one year. Populations cycle from four to five years. There is an annual cycle with a high density in the fall and a low density in spring (Odum, 1955; Meyer and Meyer, 1944). Food consists mainly of plant stems, foliage, and seeds, grasses, and insects. In large numbers they are destructive to cultivated crops causing up to 78% damage in documented cases (Meyer and Meyer, 1944). The cotton rat is in direct competition with quail for food. Large insects and quail eggs make up a substantial part of the diet. However, the cotton rat itself is food for many predators.

The host animal is considered to be S. hispidus komareki (Gardner, 1948), on the basis of geographical location (Hall and Kelson, 1959).

MATERIALS AND METHODS

Sigmodon hispidus were collected each month from June, 1970, through May, 1971, and in December, 1971, and January through March, 1972. Twenty-five live traps (mostly 16x6.5x5 cm, Sherman SN40) were set in runways throughout the collecting site and were checked each morning of the month until at least ten rats were collected at which time the traps were removed. In some months, the 750 trap days did not yield ten animals.

The trap site was in Pitt County, North Carolina, on undeveloped acreage inside the city limits of Greenville (Fig. 1, asterisk). Total area of the triangular plot of land was approximately fifty-two acres. It was bounded on all sides by paved streets. The north, east, and west boundaries were Plaza Drive, Evans Street, and Greenville Boulevard (U. S. 264) respectively. About twenty-five acres were being farmed with alternating crops of tobacco and corn. Grasses, much of which was cut periodically, were the dominant vegetation of the remaining acreage. Traps were set in an undisturbed area along Evans Street bounded by drainage ditches and small trees. The difficulty of crossing the barriers with machinery prevented farming and cutting in this area. The area was once burned-over accidently during the course of this study (February, 1971). Animals from throughout the plot had free access to the collecting area all year.

All animals were removed to the laboratory for autopsy. Rats were chloroformed and examined for parasites. Worms were rinsed in tap water and relaxed in 0.9% saline at room temperature. Cestodes were fixed in hot formol-alcohol-acetic acid (F.A.A.) and stored in 70% ethanol. Nematodes were fixed in heated 4% formalin and stored in 70% ethanol. Some larval cestodes (strobilocercus form) removed from the liver of the host were fed to a cat in an attempt to aid in the identification. One cat was fed 36 cysts over a 3 month period, while another was given 6 cysts within two months. The adult worm was subsequently recovered from one cat. Worms were stained in Mayer's paracarmine, cleared in methyl salicylate, and mounted in permount for subsequent identification. Standard histological methods were used.

Standard Chi-square statistical analyses were applied to data where applicable.

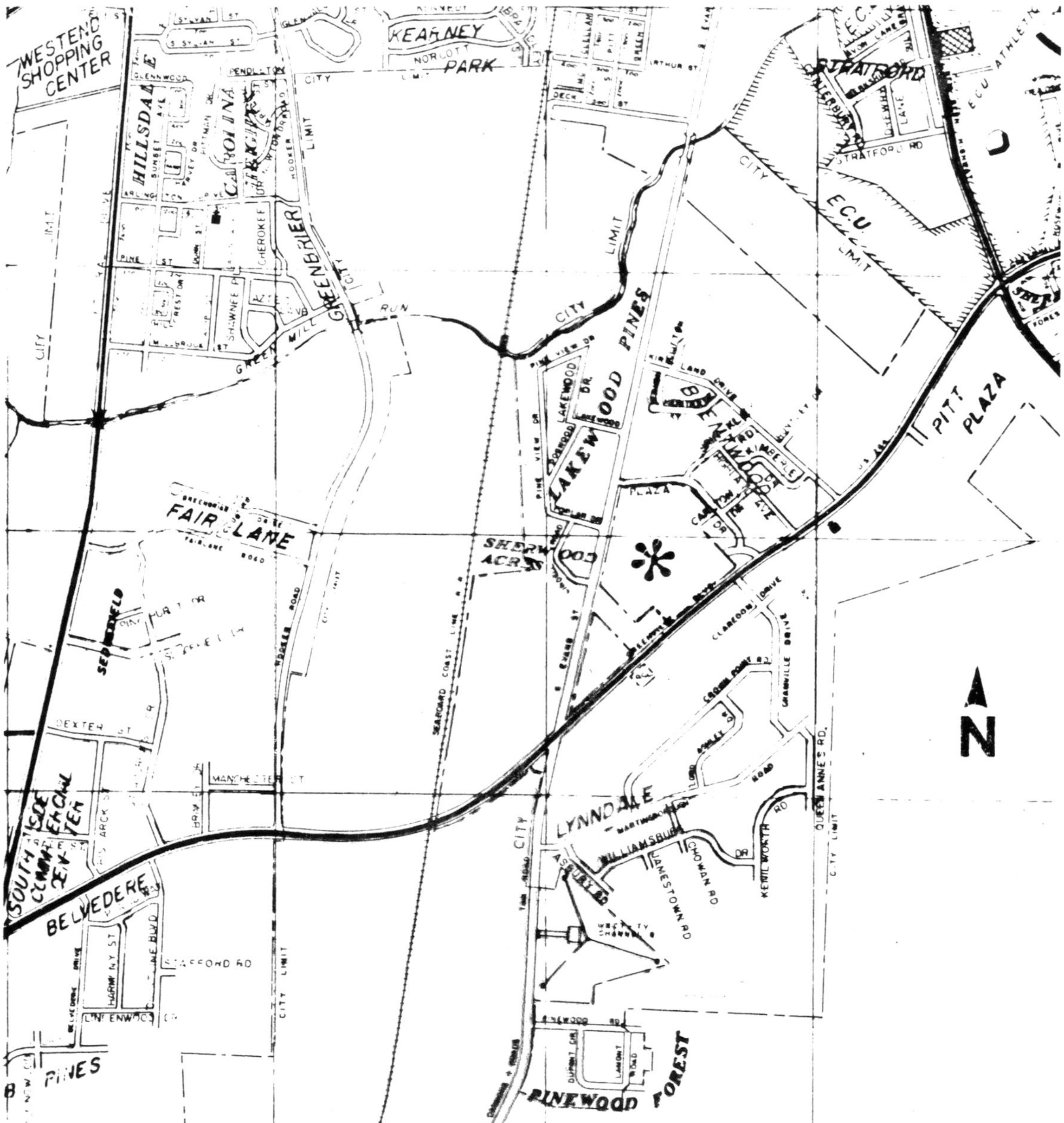

Figure 1. Map of Southwest Greenville, North Carolina. Asterisk indicates triangular collection site

RESULTS

The incidence of parasites found in *S. hispidus* over a two-year period is presented in Table I. A total of 130 cotton rats were collected and examined between June, 1970 and March, 1972. One hundred fourteen of these (87.7%) were found to be infected with one or more species of helminths. Multiple infections were common. Of 60 males and 70 females that were examined, 55 males and 59 females were found infected. There was no significant difference in collection or infection between males and females when the data were analyzed by standard Chi-square ($P<.05$).

Cotton rats were captured each month of the year, although in two months (April and May) collections were small. No males were collected in October. Most of the collection site was accidently burned during the spring of 1971, which may account for the small number of cotton rats collected during that period. However, cotton rat population density is known to exhibit an annual cycle with the lowest numbers of individuals in the spring.

Five species of parasites representing two phyla were recovered. Representing the Class Cestoidea, Phylum Platyhelminthes, were *Raillietina bakeri* (Chandler, 1942), *Hymenolepis diminuta* (Rudolphi, 1819), and larval *Taenia taeniaeformis* (Batsch, 1786). From the Class Nematoda of the Phylum Aschelminthes were *Mastophorus muris ascaroides* (Gmelin, 1790), and *Longistriata adunca* (Chandler, 1932). No other parasites were found except that 2 rats harbored 5 fleas identified as *Stenoponia americana* (U. S. Department of Health, Education and Welfare, 1964).

I. Cestoidea

A. *Raillietina bakeri*

Total: 751
Range: 1-56
Mean: 7

The most commonly occurring parasite, *R. bakeri*, was found every month of the year (Table I). The greatest number was found in September (154) with an average of 14 per host. When the data are graphed it is seen that male rats are more heavily infected than females and that the greatest occurrence of this worm is during September (Fig. 2). This species was first described from the tree squirrel, *Sciurus niger rufiventer*, in Texas by Chandler (1942). It has a retractable rostellum armed with a double circle of 66 hammer-shaped hooks, each hook being 20-22 μ in length. Mature proglottids contain 30-40 testes. It may be distinguished from *R. sigmodontis* by, respectively: number of testes: 30-40 versus 15-19; size of circus pouch: 90-95 by 35 μ versus 140 by 46 μ; number of egg capsules per segment: 80-90 versus 30-35; number of eggs per egg capsule: 6-9 versus 15-25 (Smith, 1954; Yamaguti; 1959).

B. *Hymenolepis diminuta*

Total: 16
Range: 1-4
Mean: <1

Hymenolepis diminuta appeared only infrequently and in small numbers during this study (Table I). Only 16 of these worms were recovered from 5 hosts in February, August, and October. The possibility for infection remained in the habitat since this cestode was found during August and October, 1970, and February of 1971 and 1972. When *H. diminuta* was present, the frequency of *R. bakeri* was reduced although *H. diminuta* was in low numbers (Table I). The infections were present during two seasons of the year. A winter peak was due to infections in female rats while the summer peak was due to infections in males (Fig. 3).

Hymenolepis diminuta is a cosmopolitan parasite of rodents that has been reported from man. Identification of this worm is based on number and arrangement of testes, presence of unarmed suckers, and a rudimentary rostellum (Hugghins, 1951; Wardle and McLeod, 1952).

C. *Taenia taeniaeformis*

Total: 180
Range: 1-24
Mean: 1.6

Taenia taeniaeformis was found during all months except August (Table I). The greatest number was obtained in February (40) with an average of 2.9 per host. Of the 180 strobilocerci, 142 were found in males and 38 in females (Table I), a statistically significant difference ($P<.05$). The high infection rate in males may be correlated to the size of the home range, since they are known to forage farther afield than females, or may relate to physiological differences between the sexes of hosts. The greatest occurrence of these larvae was in the spring, after which they gradually declined through August (Fig. 4).

The structure of the larva was compared to that identified by Hawkins (1942). The worm length averaged between 84 and 135 mm, and the scolex contained 2 circlets of 34-36 hooks, 0.38-0.42 mm in length.

In order to confirm identification of this worm, pieces of liver tissue containing cysts were fed to two laboratory cats. The first cat was fed 36 cysts over a three-month period between October and December, 1971. No worms were recovered from the cat after 70 days. In the second experiment, one cyst was fed on January 5, 1972, and 5 cysts on February 12, 1972. On March 17, 1972, an autopsy revealed 5 adult cestodes which proved to correspond to the description of *T. taeniaeformis*. Positive identification was made using stained preparations. After 42 days in the definitive host there still were no eggs in the terminal proglottids.

II. Nematoda

A. *Mastophorus muris ascaroides*

Total: 553
Range: 1-54
Mean: 6.8

This parasite was present throughout the year except for May. Greatest numbers were found in August and September (249), with an average of 12 per host. Male rats were more heavily infected than females and their parasite load did not fluctuate as radically as that for females (Fig. 5).

A member of the family Spirurinae, *M. muris ascaroides*, was the only parasite found in the stomach of this host. The general characteristics are two trilobed lips, unequal spicules on males, and a heavy long esophagus. Males have large cylindrical caudal alae and a gubernaculum. In females, the vulva is anterior to the middle of the body (Levine, 1968; Yorke and Maplestone, 1962).

B. Longistriata adunca

Total: 742
Range: 25-100
Mean: 13

Longistriata adunca was the second most abundant parasite found during this study (Table I). It was unevenly distributed throughout the year and found in only eight months. Male hosts were more heavily infected than females (Fig. 6). When present, it occurred in the host in large numbers (50-100). The small size and abundance of this worm made necessary an approximation of the number present. The greatest numbers occurred in February (150), with an average of 11 per host, and December (192), with an average of 9 per host. This worm was not recovered during April, May, June, or July.

This parasite is blood red in life and found spirally coiled in the upper one-fourth of the small intestine. Males have symmetrical bursa, long prebursal papillae, prominent genital cone, and long spicules (Yamaguti, 1961). The worm seldom exceeds 5-7 mm in length.

The data were compared in an effort to determine the effect of pregnancy on the degree of infection with these parasites in S. hispidus (Table II). Pregnant females were found in April, May, June, July, September, and December. Nine of 66 females (14%) were found to be carrying litters. No significant difference in worm burden was found between pregnant and non-pregnant cotton rats ($P<.05$).

It was not possible to group the hosts by age, but the data for small rats and large rats were analyzed (Table III). Longer rats had more and a wider variety of species of parasites than did shorter rats.

TABLE I

Total Number of Parasites from Sigmodon hispidus by Sex of Host for Each Month of the Year

Parasite	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Examined	3	9	8	7	6	3	1	2	1	1	5	5	8	5	7	4	3	9	0	11	3	6	15	8	60	70
Infected	3	8	8	6	6	3	1	2	1	0	3	4	6	2	7	4	3	8	0	9	3	5	14	8	55	59
Raillietina bakeri	11	29	14	17	29	8	0	6	7	0	32	32	69	18	83	41	98	56	0	54	7	14	45	47	429	322
Hymenolepis diminuta	0	0	1	4	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	2	0	0	0	0	10	6
Taenia taeniaeformis	4	12	35	5	49	4	0	3	4	0	10	4	1	1	0	0	2	0	0	1	7	1	30	7	142	38
Mastophorus muris ascaroides	12	40	7	3	16	12	1	0	0	0	11	22	41	1	112	10	72	35	0	27	25	25	34	47	331	222
Longistriata adunca	10	40	125	25	100	0	0	0	0	0	0	0	0	0	10	0	100	0	0	110	0	30	115	77	460	282
Total	37	121	182	54	194	24	1	9	11	0	53	58	111	20	214	51	272	91	0	194	39	70	224	178	1338	870

Table II

Number of Parasites from Non-pregnant and Pregnant

Female Sigmodon hispidus

Parasite		Condition	
		Non-pregnant	Pregnant
	Number	57	9
Raillietina bakeri		263* (5.6)**	51 (6.4)
Hymenolepis diminuta		6 (0.1)	--
Taenia taeniaeformis		27 (.6)	7 (.9)
Mastophorus muris ascaroides		195 (4.2)	27 (3.4)
Longistriata adunca		257 (5.5)	--

*total number
**mean number

Table III

Parasite Load in Relation to

Host Body Length

Body length (cm)	Number of parasite species	Average number of worms
8-10	4	1.4
13-15	5	5.4

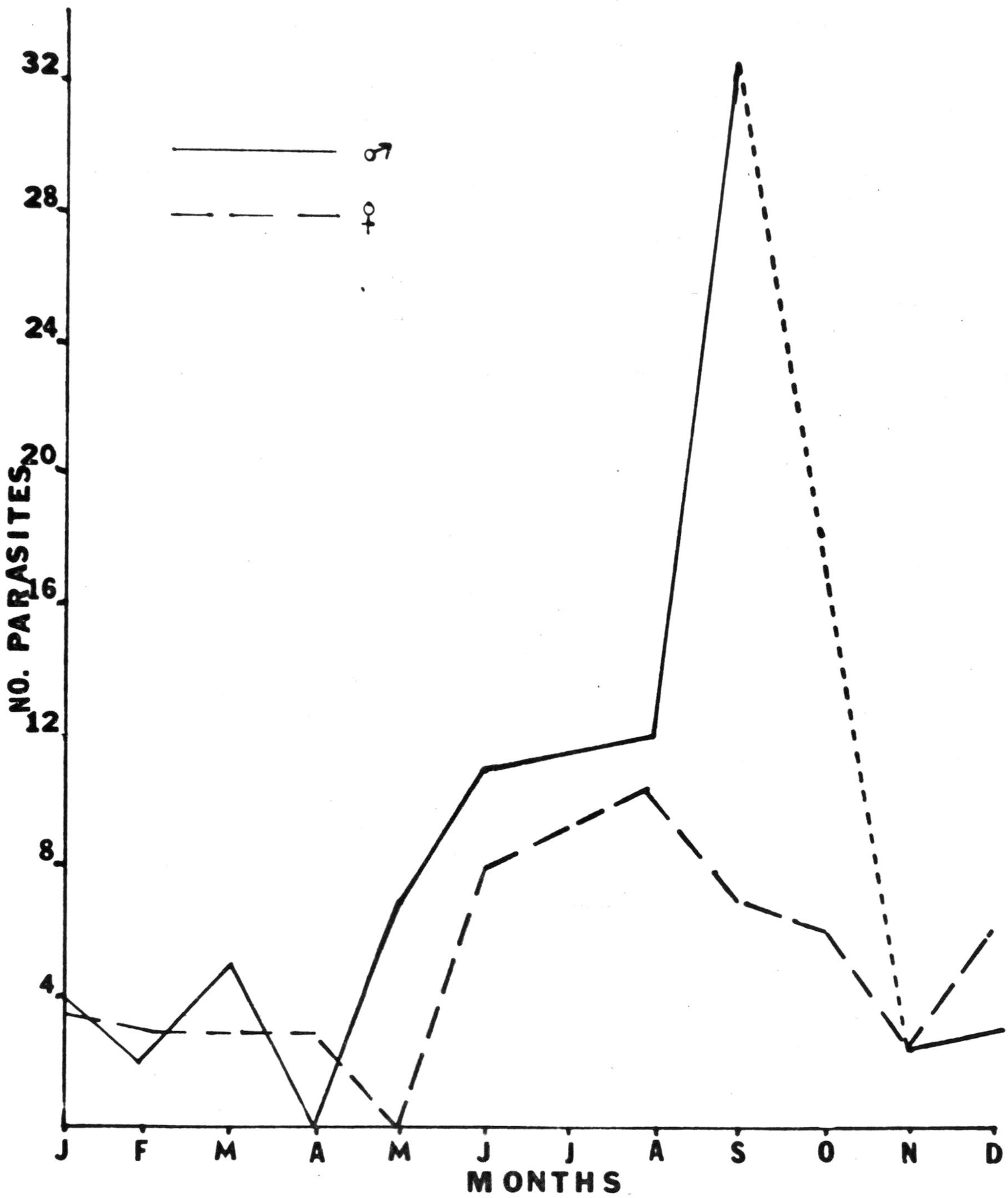

Figure 2. Annual Mean Incidence of Raillietina bakeri in Male and Female Sigmodon hispidus

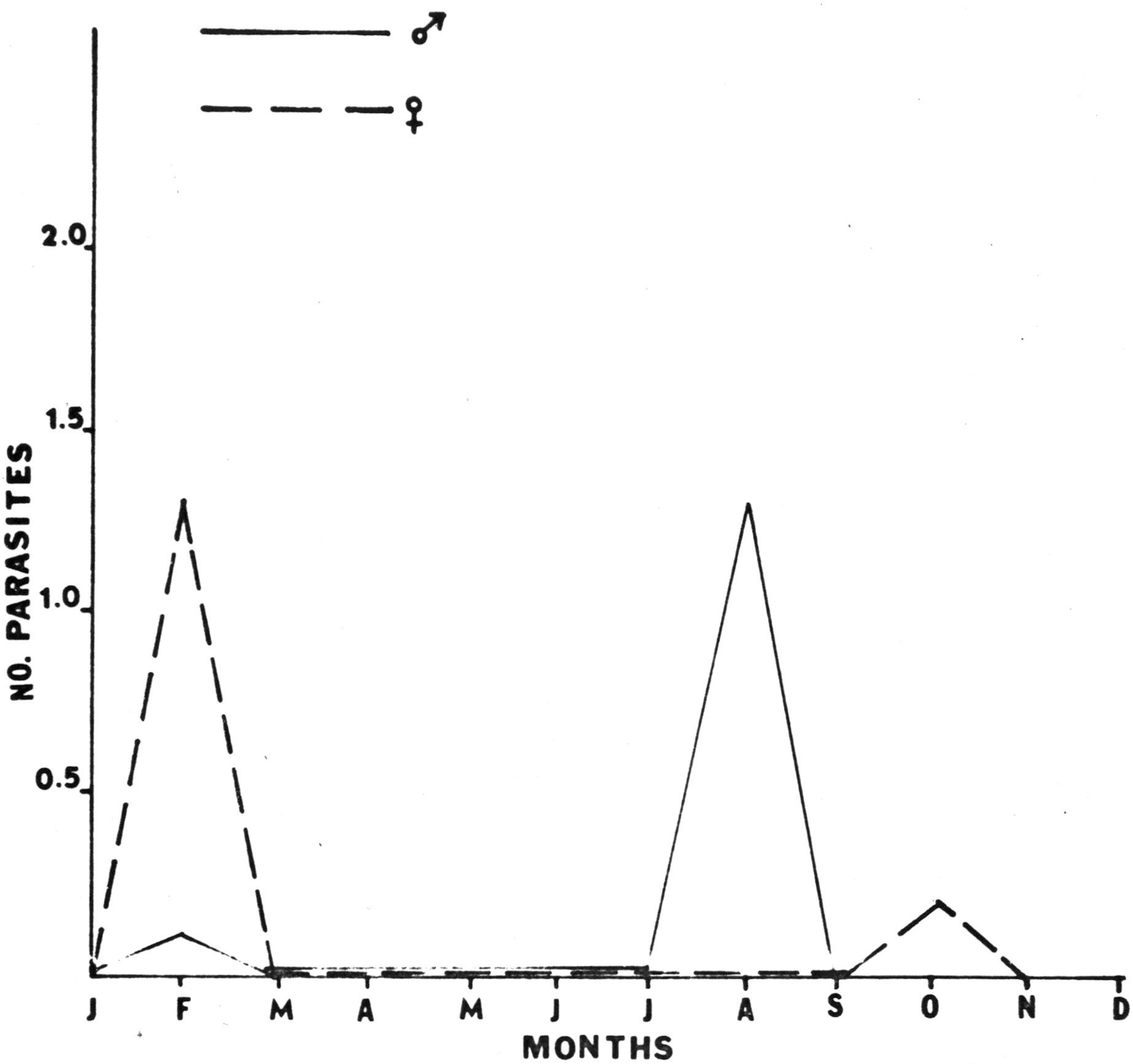

Figure 3. Annual Mean Incidence of Hymenolepis diminuta in Male and Female Sigmodon hispidus

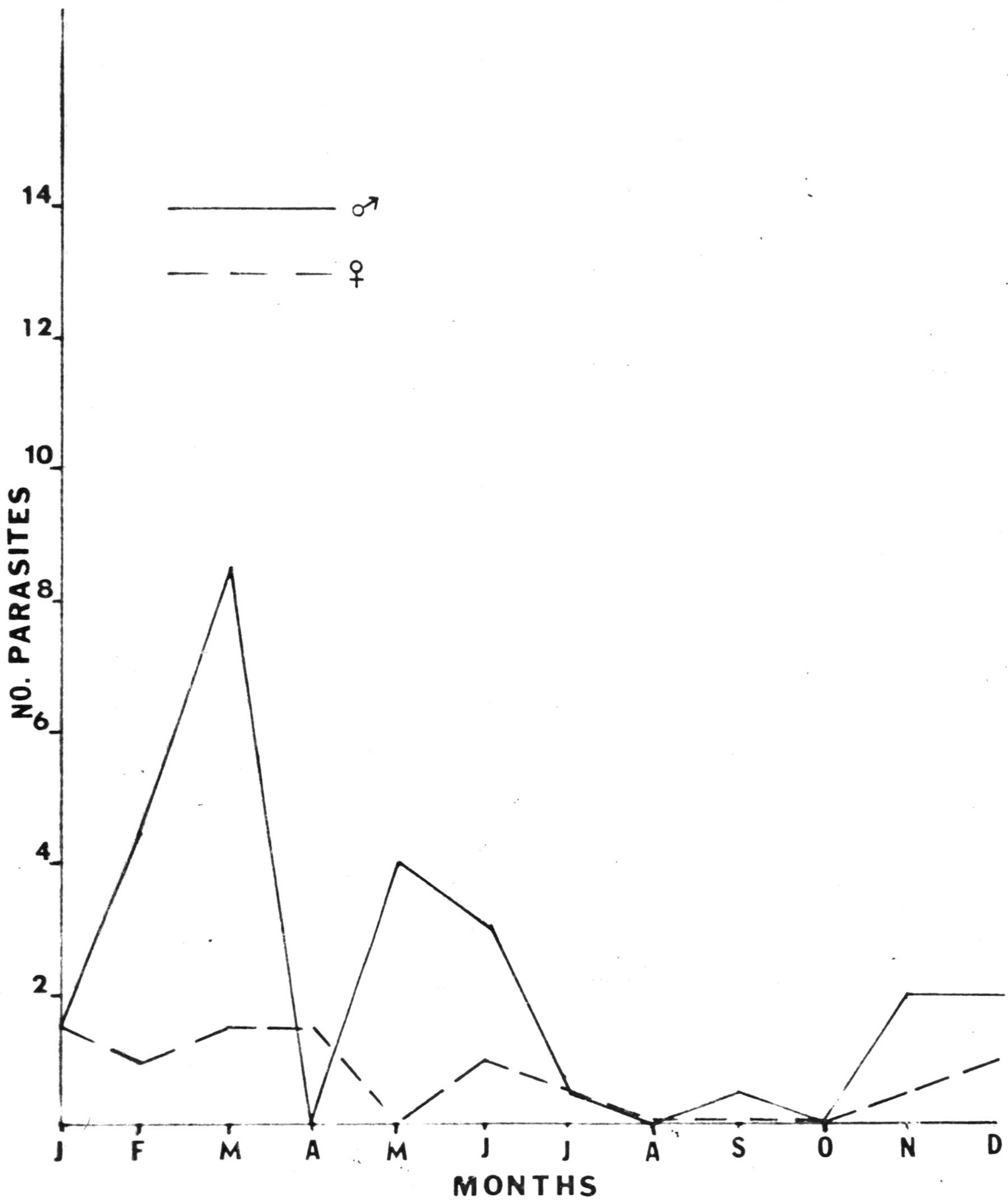

Figure 4. Annual Mean Incidence of _Taenia taeniaeformis_ in Male and Female _Sigmodon hispidus_.

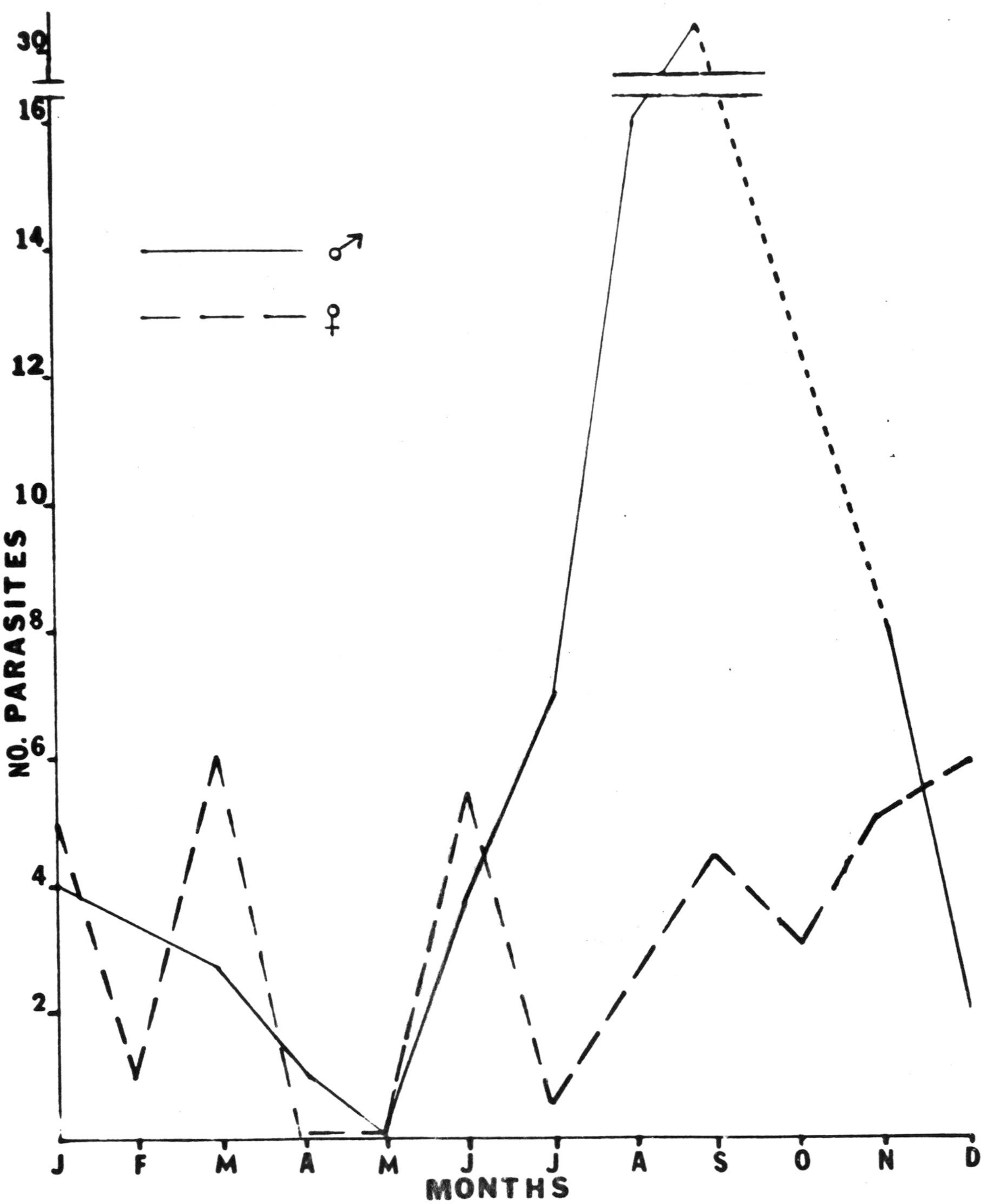

Figure 5. Annual Mean Incidence of Mastophorus muris ascaroides in Male and Female Sigmodon hispidus

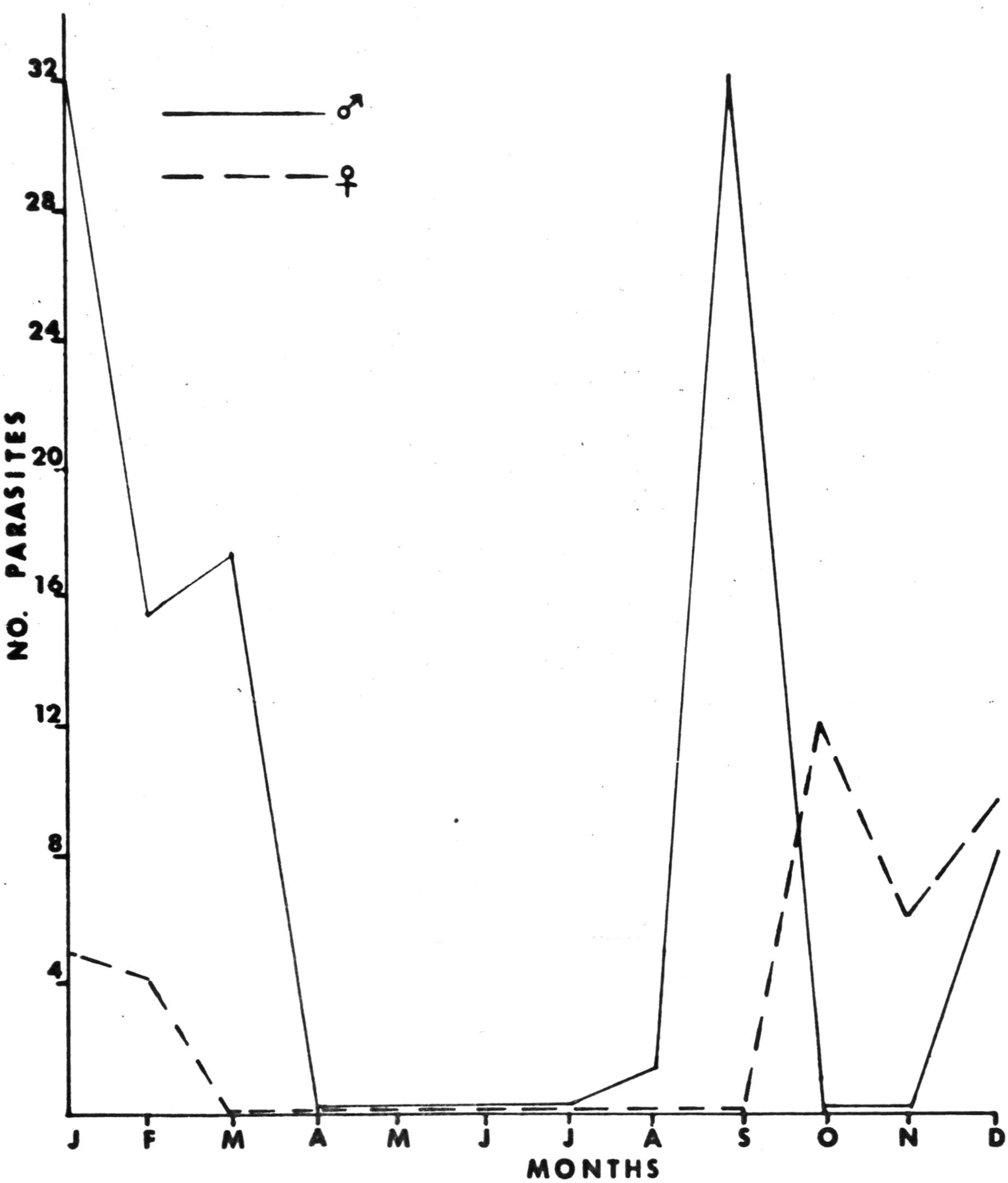

Figure 6. Annual Mean Incidence of Longistriata adunca in Male and Female Sigmodon hispidus

DISCUSSION

The systems approach to parasite ecology is new but has gained much interest in recent years. The basic ideas are discussed by Kennedy (1970). There are two types of systems for which vertebrate animals may serve as models--the definitive or intermediate host system. In the definitive host model, represented by the host and parasite-mix, input to the system is usually by the orifices of the body, and less frequently by penetration. Once inside the host most parasites inhabit the gastro-intestinal tract or associated areas. The host animal serves as an environment for the parasite and provides all essential factors necessary for life. This is a dynamic system affected by both biotic and abiotic factors. Host diet, age, behavior, and hormonal balance affect the parasites and the parasites affect the host in turn. Daily temperature changes, long-term climatic factors, and seasonal changes have an effect not only on host but also the parasite-mix. Further, there are interactions between the species of parasites (Holmes, 1961; 1962). There is ready escape from this system within the intestinal tract so there can be a rapid turnover of parasite load. In the intermediate host system, there is less interaction between abiotic factors and the parasite because most parasites which are larval in vertebrates are located within the tissues. There may be a greater interaction between host and parasite because of this intimate association. Escape from this intermediate host system is by death of the host; there is no ready access to the outside. Thus, there can be no rapid turnover of parasite load. The cotton rat, S. hispidus, can be used as an example model for both systems. The cotton rat serves as an intermediate host for the cestode T. taeniaeformis, while the other parasites recovered reach sexual maturity in the intestinal tract.

An attempt was made to group the host animals into age classes in order to observe the effect of host age on parasite load. Some workers (Layne, 1969; Luttermoser, 1936) have used weight as an index of age. But Dunaway (1964) has shown that weight is not necessarily indicative of age. She found that average weights of females were greater than males in breeding season but males were heavier during the rest of the year. During cold weather animals either lost weight or gained weight slowly. I attempted to use body length (snout-vent) as an index of age. This proved unsatisfactory since most animals fell within a narrow range (12-14 cm), although the total range was from 6 to 16 cm. This indicates that juveniles rapidly attain the same length as mature adults in the population. No age classes were delineated because of this problem. However, since cotton rats seldom live more than a year in the wild their parasite-mix is representative of only a relatively short-term situation. It was observed that longer (older?) rats had more and a wider variety of parasites than did short (young?) rats (Table III). A random sample was taken from the data to compare both variety and intensity of infection in rats of different sizes. Table III is based on 7 animals in each of two size classes. The first class (8-10 cm) represents what I consider to be juvenile rats and the second (13-15 cm) represents mature adults.

Dogiel (1961) discusses the biotic factor of age. He found that there are three basic types of parasite populations:

1) parasites independent of age of the host;

2) parasite abundance decreasing with age of the host;

3) parasite abundance increasing with age of the host.

The parasites of *S. hispidus* fall in to the last group. Cotton rats live about one year on the average and rarely more than the fifth season. Thus, an "old" host, one 13-15 cm in length, may be only six months of age. This is in contrast with other vertebrates that live for several years and for which definite age classes may be established. The accumulation of parasites is terminated by host death, so parasite longevity is of little importance to the cotton rat model. Read (1967) showed by surgical transplantations that *H. diminuta* could survive in rat hosts for 14 years, an accomplishment of seemingly little importance to the worm if the host dies within one year. It is further detrimental to the parasite if its life cycle is adapted to this long-lived adult. That is, if the developmental stages are extended over a long period then fewer adults will show up in short-lived hosts. This may be why few of these worms were found in cotton rats.

Behavior of the host animal will have an effect on the parasite population. Behavior, or mode of life, is determined by the animal's geome and environment. The feeding behavior of an animal is important in determining the intensity of infection and which parasites it harbors. The cotton rat feeds on plants, insects, and, in my study area, on scraps of food foraged from nearby houses. The cotton rat is a terrestrial animal that does not need to drink standing water so one would not expect to find a parasite-mix including many species whose life cycle involve aquatic larvae, such as trematodes. Some species of cestodes and nematodes have life histories which involve terrestrial invertebrates or have no intermediate host at all and, therefore, would be expected to be found among cotton rat parasites. Stomach contents of several animals showed a variety of animal remains, much of which corresponded with the intermediate hosts of the parasites recovered (slugs, beetles, roaches).

If an intermediate host is needed it is the availability of these hosts to the definitive host which will determine the extent of infection. There must be ample contact between the two hosts to insure completion of the life cycle of the parasite. The intermediate host of Raillietina bakeri is probably a land slug or snail (Olsen, 1967). Many slugs occurred in the area, but cystocercoids were not found in several which were autopsied. Hymenolepis diminuta and M. muris ascaroides use a wide variety of insects and fleas (Yamaguti, 1959). These arthropods were in the habitat, but no helminth larvae were found in those beetles and roaches autopsied. Longistriata adunca, if its life history is similar to that of its close relative Nippostrongylus muris (see Hugghins, 1951), does not require an intermediate host. Eggs which are voided in the feces hatch, and the larva reinfects the host by penetration.

It has been established that certain parasite species show definite seasonal variation (Esch and Gibbons, 1967; Kohlweiss, 1971; McDaniel and Coggins, 1972; McDaniel and Bailey, 1972). Luttermoser (1936) made a one-year study of Baltimore house rats and found they had greater helminth infections in summer. Hymenolepis diminuta showed a slight seasonal adjustment, a 13% infection rate in winter and 22% in summer. This small variation may be attributed to the greater availability of insect intermediate hosts in summer. These figures approximate those found for H. diminuta in S. hispidus by Harkema and Kartman (1948) but are far higher than the infection rate of 4.4% for H. diminuta in my study. A seasonal cycle was observed for H. diminuta with two equal peaks in winter and summer (Fig. 3).

Layne (1969) studied seasonal variation of the nematode Capillaria hepatica in three rodents of Florida, one of which was S. hispidus. His study showed that infection with C. hepatica was high in April (100%) and low throughout the winter. My study shows April as the month of lowest occurrence of all species, although no C. hepatica was recovered. Climate may account for the early peak of infection in Florida rodents. Still, both studies show a single high infection period during the year. Layne's study is difficult to evaluate since data were not accumulated systematically for each month over the eight-year period. The study by Harkema and Kartman (1948) is most applicable to the present study. This work was done in the piedmont region of North Carolina. They found an average of 8.09 R. bakeri per host; 6.22 H. diminuta per host; 1.75 T. taeniaeformis per host; 10.92 M. muris ascaroides per host; and 36.3 L. adunca per host. Also found were H. microstoma and Andrya microti, worms not recovered by me. The mean number of worms found in their study compares favorably with mine (Table I). In their study L. adunca, T. taeniaeformis, and H. diminuta were found to exhibit seasonal changes in density. Spring (March-May) and fall (September-November) were the times of peak infection. I found seasonal variation in all parasites recovered. The population density of parasites was greatest in winter (January-March) and summer (July-September). Note that in the study of Harkema and Kartman winter begins in December while in mine it is indicated as beginning in January, as in eastern North Carolina cold weather is intermittent before the end of December. Further, Harkema and Kartman group the data by season while I plotted the data for each month of the year. This might account for some slight differences in when peaks of infection are shown to occur, but the indication is that parasite life cycles in piedmont North Carolina are shifted to different seasons than those of the coastal habitat.

Since all parasites recovered in my study showed seasonal variation, the dynamics of each will be discussed separately. The mean number of parasites per month per sex of host is plotted in Figures 2-6.

Figure 2 shows that R. bakeri has its greatest occurrence in September (summer). The winter infection rate fluctuates, but R. bakeri is present from January through March. The mean number of parasites per host is approximately 4 during the winter but rises to a mean number of 32 in September. The recruitment period for R. bakeri is in spring. The number begins to rise in May. Since land slugs are the intermediate hosts for R. bakeri, the high rate of infection in summer may be a direct result of the infected slugs being eaten by cotton rats in the spring and the worms maturing during the summer in the definitive host. A plateau is reached in June and July, followed by a sharp increase in infection from August through September and a precipitous drop in October. This sharp drop may be associated with a die-off of parasites and biotic and abiotic effects on the host, which in turn affects the parasites. The incidence of this worm never reaches zero, but it exists in small numbers throughout the winter. Undoubtedly, these few worms provide eggs in spring for the next annual cycle of increase. During the summer the temperature of this geographical area is high enough and the rainfall low enough potentially to retard development of the larval stages of the various parasites. The absence of slugs during the dry summer might explain the sharp drop of R. bakeri between September and October. The die-off at the end of summer may signal the end of the parasite's natural life span. The graph indicates that males are much more heavily infected than females. Spring is the season of intense mating in the cotton rat and females are confined to the nest with a litter while the male searches for food. This correlates with the higher infection rate in males in the summer infection period. There is not as much difference between winter peaks and presumably breeding would have dropped to an extreme low at that time. A total of 9 pregnant females were caught during various months (Table II). These data indicate that mating does not cease after the heavy spring activity.

Peaks of infection in H. diminuta occur in August and February (Fig. 3). These peaks come in winter and summer but the winter peak is due to infection in females while the summer peak is due to infection in males. This may be due to the greater activity of males in spring, although the number of infections were so low as to make firm statements impossible. This worm does appear to follow an annual cycle of increase similar to R. bakeri.

Mastophorus muris ascaroides has a high summer occurrence (September) and declines through the winter to a low in May (Fig. 4). This gradual loss might be explained by examining the intermediate hosts, cockroaches and fleas. The flea, an ectoparasite or burrow-dweller, has a less variable environment than other intermediate hosts. Perhaps this allows the larval M. muris ascaroides to continue development and be picked up by the cotton rat in small numbers through the winter. The rise in rate of infection indicates that greatest recruitment occurs from late spring through the summer, a time when invertebrate hosts are active.

Longistriata adunca acquires its parasites in dramatic bursts (Fig. 5). In a one-month period, infection may jump from a mean of 1 to a mean of 32 parasites per host. Female hosts do not show as great a seasonal periodicity as do males, although they acquire their parasites at about the same time. Longistriata adunca probably has no intermediate host but gains entrance by penetration (Hugghins, 1951). Eggs hatch from feces of cotton rats putting the larvae in proximity to the same or another rat. The cotton rat may defecate in or near the nest giving the larvae the opportunity to infect the host. The habits of cotton rats may account for both the precipitous rise in infection and the high levels attained. It is easy to postulate that rats defecate nearer the nest during the winter than they do during the spring and summer.

Hormonal levels may affect the degree of parasitism with this worm. It appears there may be a lower rate of infection of *L. adunca* in female cotton rats (because of the high levels of estrogens?). The difference between parasite loads in males and females is not significant for other worms, but *L. adunca* shows definite differences for which host behavior alone cannot account. No pregnant females harbored *L. adunca* (Table II) and the mean infection rate for females was less than half that for males (Table I). Similar data were obtained by Frayha, Lawlor, and Dajani (1971) for *Echinococcus granulosus* infections in albino mice.

Taenia taeniaeformis is a larval parasite of the cotton rat. There is only one recruitment period for this parasite, in the summer (Fig. 6). The peak of infection is observed in late winter (March); the numbers continue to fall through August, after which they begin to rise again toward the high of winter. The factor of parasite and host life-span cannot be ignored in this case since there is no escape from the liver tissue of the cotton rat.

The cat is the definitive host of *T. taeniaeformis*. Eggs are passed in the feces and picked up by the cotton rat in its foraging for food. The onchosphere penetrates the intestine and goes via the bloodstream to the liver, usually appearing within 96 hours. Cysts start to form about day 7, the scolex by day 14, and the strobila around day 48 (Abuladze, 1970). The lack of success in establishing infections in cats with *T. taeniaeformis* larvae recovered from rats from October through January would seem to indicate that they were not mature and infective before February. Hutchison (1958) showed that larvae had to undergo a minimum period of 60 days in the laboratory mouse before becoming infective, so cotton rats at the Greenville site apparently did not acquire this infection before late fall. Since cotton rat populations are low during the spring, it may extend into summer the period before which many cats may pick up the infection. Hutchison (1959) reported that the adult worm sheds gravid proglottids between 36-42 days after infection of the cat, so this would seem to make eggs available for cotton rats at the proper time in late fall, when host population densities are high, to complete the life history as indicated by my collections. An age resistance to infection has been established for laboratory mice (Hutchison, 1958), so perhaps only rats born in the summer are susceptible to infection.

There appears to be little difference between pregnant and non-pregnant female cotton rats in infection with helminths (Table II). The degree of infection is greater in two species of helminths of pregnant rats, lesser in one. Two cannot safely be compared since no parasites of these species were found, and they occurred in low numbers throughout. There is no evidence to indicate these rates are influenced by host sex or pregnancy except, perhaps, for *L. adunca* as was previously discussed.

SUMMARY

1. *Sigmodon hispidus komareki* inhabiting broomsedge fields in eastern North Carolina harbored *Raillietina bakeri*, *Hymenolepis diminuta*, larval *Taenia taeniaeformis* (Cestoda), and *Mastophorus muris ascaroides* and *Longistriata adunca* (Nematoda).
2. Seasonal cycles of abundance were indicated for all species of helminths recovered. Adult parasites showed greater occurrence in summer and winter. The larval *Taenia taeniaeformis* showed only one period of increase, in winter.
3. Sex of host affected the kinds and numbers of parasites. Male cotton rats were more heavily infected than female rats.
4. Age of host appeared to have an effect on the degree of parasitism. Old rats had more parasites and a wider variety of parasites than young rats. The use of various indexes of age was discussed.
5. Physiological-endocrine differences appeared to have no significant effect on parasite loads. No significant difference was seen in degree of infection between pregnant and non-pregnant female cotton rats. *Longistriata adunca* may be the exception as no pregnant female rats harbored this worm and the mean infection load was less than half that for male rats.
6. Effects of host diet and behavior on the number and kinds of parasites were discussed.
7. The life cycle of each parasite found was reviewed.

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