

ECTOPARASITES AND GASTROINTESTINAL HELMINTHS OF SOUTHERN FLYING SQUIRRELS IN SOUTHEAST GEORGIA

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ABSTRACT: Southern flying squirrels (*Glaucomys volans*) from southeastern Georgia were examined for ectoparasites and gastrointestinal helminths. Ten species of ectoparasites were recovered, including 3 species of sucking lice (*Hoplopleura trispinosa*, *Microphthirus uncinatus*, and *Neohaematopinus sciuropteri*), 1 species of flea (*Orchopeas howardi*), 2 species of ticks (*Amblyomma maculatum* and *Ixodes scapularis*), 3 species of mesostigmatid mites (*Androlaelaps casalis*, *A. fahrenheiti*, and *Haemogamasus ambulans*), and 1 species of chigger (*Leptotrombidium peromysci*). Only the sucking lice and fleas were common on this host. *M. uncinatus* is reported for the first time from eastern North America. The 2 most commonly collected ectoparasites, *N. sciuropteri* (prevalence = 63%) and *O. howardi* (prevalence = 47%), have previously been shown to be vectors of the rickettsial zoonotic agent that causes sporadic epidemic typhus. Also, 3 nematodes (*Citellinema bifurcatum*, *Strongyloides robustus*, and *Syphacia thompsoni*), 1 unidentified cestode, and 1 acanthocephalan (*Moniliformis clarki*) were found in flying squirrel gastrointestinal tracts. With the exception of *S. thompsoni*, which was common and relatively abundant in the cecum (prevalence = 94%, intensity = 51 ± 12), both the prevalence and intensity of helminth parasites were low. The nematode *S. thompsoni* and the acanthocephalan *M. clarki* are new state records for tree squirrels in Georgia.

Southern and northern flying squirrels (*Glaucomys volans* and *G. sabrinus*) differ from other North American tree squirrels in that they are smaller in size, strictly nocturnal, more carnivorous, and spend less time on the ground (Dolan and Carter, 1977). *G. volans* is the only species of flying squirrel found southeast of the Appalachian mountains, where it often nests in red-cockaded woodpecker (*Picoides borealis*) cavities (Jackson, 1994). As part of a study concerning the impact of southern flying squirrels on the reproductive success of this endangered woodpecker, flying squirrels in the vicinity of red-cockaded woodpecker cavities at Fort Stewart, Georgia were trapped and killed (Mitchell et al., 1999). These squirrels were examined during the present study to determine the prevalence and intensity of ectoparasites and gastrointestinal helminths. This is important because there are relatively few accounts of the ectoparasite faunas associated with North American flying squirrels and no report on the parasitic helminths of flying squirrels in the state of Georgia. We anticipated that the arboreal behavior of *G. volans* and the annual prescribed burning of the study locality might affect the parasite faunas associated with these squirrels. In addition, 2 species of ectoparasites that occur on flying squirrels, the sucking louse *Neohaematopinus sciuropteri* and the flea *Orchopeas howardi*, have potential medical importance. Both species are laboratory vectors of a strain of the rickettsial agent *Rickettsia prowazekii* that causes sporadic epidemic typhus across much of North America (Sonnenshine et al., 1978; McDade, 1987). Therefore, we were especially interested to determine whether we would collect these species during our survey.

MATERIALS AND METHODS

The study locality was Fort Stewart Military Reservation, a 111,600-ha site in the lower coastal plain of southeastern Georgia (ca. 32° N,

81° W). During 1996 and 1997, southern flying squirrels were captured in or around nests of the red-cockaded woodpecker in open pine forest consisting mainly of longleaf pine (*Pinus palustris*), and grasslands/low vegetation maintained by prescribed burning (Mitchell et al., 1999). Flying squirrels in woodpecker nests were grasped with a mechanical pickup tool, whereas others were captured using Sherman live traps (7.5 × 9.0 × 25.5 cm) baited with peanut butter and placed on a horizontal platform 1.5 m aboveground. Flying squirrels were killed by cervical dislocation and stored frozen in zip-lock bags until they were examined for parasites. Collection of flying squirrels was approved by the Georgia Department of Natural Resources, the U.S. Fish & Wildlife Service (permit 21329-G), and the Fort Stewart Provost Marshall (permit 0274-96).

Ectoparasites were recovered from 70 southern flying squirrels (28 males, 42 females) using a slight modification of the washing technique described by Henry and McKeever (1971). Briefly, each squirrel was thawed at room temperature for 30 min and placed inside a 500-ml jar containing approximately 250 ml of water and a few drops of liquid household dishwashing detergent. The jar was then capped and vigorously shaken for 30 sec, after which the squirrel was removed and rinsed with 70% ethanol to remove residual detergent and any remaining ectoparasites. The contents of the jar were then filtered through a fine mesh and, using a dissecting microscope, ectoparasites were collected with fine forceps. Some specimens were cleared in potassium hydroxide (lice) or lactophenol (mites) and slide-mounted to facilitate identification.

The gastrointestinal tracts from 33 southern flying squirrels (14 males, 19 females) were examined for helminths. The small intestine and large intestine were each placed in individual Petri dishes, covered with water, cut open, and then gently scraped with insect pins during examination using a dissecting microscope (×8 total magnification). Stomach contents were washed through a fine mesh screen before examination. Helminths were preserved overnight in 5% formalin and then transferred to 70% ethanol.

Voucher ectoparasite specimens are deposited in the Institute of Arthropodology and Parasitology at Georgia Southern University under accession numbers L2586-L2621 and L2623-L2656. Voucher helminth specimens are deposited in the Harold W. Manter Laboratory (University of Nebraska, Lincoln, Nebraska) under accession numbers HWML 15058-15062. Ecological terms follow Bush et al. (1997).

RESULTS

Ten species of ectoparasites were collected from southern flying squirrels including 3 species of sucking lice, 1 species of flea, 2 species of ticks, 3 species of mesostigmatid mites, and 1 species of chigger (Table I). However, only lice (especially *N. sciuropteri*) and the flea were common.

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TABLE I. Infestation parameters for ectoparasites of 70 southern flying squirrels from Fort Stewart, Georgia.

Ectoparasites*	Prevalence (%)	Mean intensity	Intensity range	Total†
Sucking lice				
<i>Neohaematopinus sciuropteri</i>	63	7.8	2-34	79M, 102F, 164N
<i>Hoplopleura trispinosa</i>	20	4.1	2-10	16M, 41F, 1N
<i>Microphthirus uncinatus</i>	16	5.7	2-13	25M, 34F, 4N
Flea				
<i>Orchopeas howardi</i>	47	3.7	1-22	41M, 80F
Ticks				
<i>Amblyomma maculatum</i>	1	1.0	1	1F
<i>Ixodes scapularis</i>	1	1.0	1	1N
Mesostigmatid mites				
<i>Androlaelaps casalis</i>	6	2.0	1-3	8F
<i>Androlaelaps fahrenheitsi</i>	4	1.7	1-2	5F
<i>Haemogamasus ambulans</i>	1	1.0	1	1F
Chigger				
<i>Leptotrombidium peromysci</i>	10	1.9	1-3	13L

* Nine squirrels were parasitized by 0 ectoparasite species, 22 by 1 species, 25 by 2 species, 11 by 3 species, 1 by 4 species, and 2 by 5 species.

† M, males; F, females; N, nymphs; L, larvae.

Five species of helminths were found in the gastrointestinal tract of the flying squirrels (Table II). The most common was the pinworm *Syphacia thompsoni*, which was found primarily in the cecum. Low numbers of the other helminths were found in the small intestine of 11 of the 33 squirrels we examined, usually only 1 species per squirrel, either *Strongyloides robustus* (6 squirrels) or *Citellinema bifurcatum* (3 squirrels). Parasites found in the small intestine were generally confined to the duodenum.

DISCUSSION

Flying squirrels are parasitized by relatively rich faunas of ectoparasites. Accounts of the ectoparasites associated with flying squirrels include contributions by Spencer (1955) and Whitaker et al. (1983) for ectoparasites of the northern flying squirrel in British Columbia and Oregon, respectively, and Whitaker (1982) and Sonenshine et al. (1978) for ectoparasites of the

southern flying squirrel in Indiana and Virginia, respectively. General mammal ectoparasite surveys that include data on ectoparasites of *G. volans* include works by Morlan (1952) for southwestern Georgia, Wilson (1961) for Indiana, and Forrester (1992) for Florida. Timm (1975) included records of ectoparasites recovered from *G. sabrinus* in his mammal survey in northeastern Minnesota. In addition, Whitaker and Wilson (1974) listed parasitic mites, and Kim et al. (1986) and Durden and Musser (1994a, b) documented sucking lice recorded from both species of North American flying squirrels. Some of the ectoparasites associated with North American flying squirrels, such as 3 species of sucking lice and at least 2 species of fleas, appear to be host-specific to *Glaucomys*, but show little apparent preference between the northern and the southern flying squirrel.

The most remarkable ectoparasite we recovered from Georgia flying squirrels is the monotypic enderleinellid sucking

TABLE II. Infection parameters for helminths found in the small intestine (SI) and large intestine (LI) of 33 southern flying squirrels from Fort Stewart, Georgia.

Helminth species*	Site of infection	No. infected (prevalence)	Mean intensity \pm SE	Intensity range
Acanthocephala				
<i>Moniliformis clarki</i>	SI	1 (3%)	1	1
Cestoda				
Undetermined species	SI	1 (3%)	ND	ND
Nematoda				
<i>Citellinema bifurcatum</i>	SI	4 (12%)	3 \pm 1	1-5
<i>Strongyloides robustus</i>	SI	8 (24%)	3 \pm 1	1-8
<i>Syphacia thompsoni</i>	LI†	31 (94%)	51 \pm 12	1-321

* Two squirrels were parasitized by 0 helminth species, 20 by 1 species, 9 by 2 species, 1 by 3 species, and 1 by 4 species.

† Most individuals (93%) were found in the cecum.

louse *Microphthirus uncinatus*, the smallest louse in the world. Adult females measure 0.45 mm and adult males 0.35 mm (Kim et al., 1986). Although this louse has previously been recovered from North American flying squirrels, until now it was known only from British Columbia, California, Oregon, and Minnesota (Spencer, 1955, 1966; Whitaker et al., 1983; Kim et al., 1986; Durden and Musser, 1994a). Therefore, we have greatly expanded the known range of this louse and suspect that it is probably widespread in North America wherever flying squirrels occur, but that its tiny size has precluded it being widely recorded. We recovered 2 additional species of sucking lice, the hoplopleurid *Hoplopleura trispinosa*, and the polyplacid *N. sciuropteri*. Both are widespread ectoparasites of *G. sabrinus* and *G. volans* in North America (Morlan, 1952; Spencer, 1955, 1966; Wilson, 1961; Timm, 1975; Harlan and Kramer, 1979; Whitaker, 1982; Whitaker et al., 1983; Kim et al., 1986; Forrester, 1992; Durden and Musser, 1994a).

Only 1 species of flea, the ceratophyllid *Orchopeas howardi*, was recovered from flying squirrels in this survey. This flea is a widespread generalist ectoparasite of tree squirrels in North America, especially in the eastern United States (Durden and Kollars, 1997). In comparison, Whitaker et al. (1983) recovered 12 species of fleas from *G. sabrinus* or their nests in Oregon. Also, Benton and Day (1980) recorded 4 species of fleas in *G. volans* nest boxes in New York and Vermont, including the *Glaucomys*-specific species *Eptedia faceta* and *Conorhinopsylla stanfordi*.

Ticks were rare on flying squirrels in this survey, with only single individuals of 2 ixodid species being recovered. However, both species have medical significance. The Gulf Coast tick (*Amblyomma maculatum*) often feeds on humans and companion animals in the southern United States and can cause paralysis, and the blacklegged tick (*Ixodes scapularis*) is the principal vector of the spirochetal agent of Lyme borreliosis in the eastern United States (Felz and Durden, 1998). In Virginia, Sonenshine et al. (1978) recorded 3 species of ticks from *G. volans*; immatures of *Dermacentor variabilis*, *I. marxi*, and *I. scapularis*. None of these species was common in their survey.

We recovered 3 species of mesostigmatid mites, all laelapids and none common. All of these species have previously been reported from *Glaucomys* (Morlan, 1952; Whitaker and Wilson, 1974; Timm, 1975; Sonenshine et al., 1978). Another laelapid mite, *Haemogamasus reidi*, has also been reported from *G. volans* (Sonenshine et al., 1978; Williams et al., 1978; Harlan and Kramer, 1979).

Leptotrombidium peromysci was the only species of chigger recovered. This widespread chigger parasitizes many species of small mammals in the United States, including sciurid rodents (Whitaker, 1982). Another chigger (*Neotrombicula fitchi*) has been reported from *G. volans* in Indiana and New Jersey (Sonenshine et al., 1978; Harlan and Kramer, 1979).

As anticipated, we collected relatively large numbers of lice and fleas. Few ticks or chiggers were collected, presumably reflecting the relatively small amount of time that *G. volans* spends on the ground where these ectoparasites quest for hosts. Prescribed burning carried out annually at the study locality may also account for low tick and chigger populations. We were surprised that only 14 individual mesostigmatid mites were recovered from 70 flying squirrels. However, other workers have also reported few mesostigmatids on these rodents. Because fly-

ing squirrel nests would appear to be good habitats for colonization by blood-feeding mesostigmatid mites, it would be intriguing to determine why these mites are rare on flying squirrels.

The 2 most abundant ectoparasites in this study were *N. sciuropteri* and *O. howardi*, 2 species implicated as the principal vectors of the rickettsial agent of sporadic epidemic typhus (Sonenshine et al., 1978; McDade, 1987). It would therefore be interesting to determine the incidence of infection of flying squirrels in our study site with this pathogen, and to determine the enzootiology and epidemiology of any associated disease.

The prevalence of parasitic helminths of sciurids such as the gray squirrel (*Sciurus carolinensis*) and the fox squirrel (*S. niger*) has been determined throughout much of the range of these hosts (reviewed by Rausch and Tiner 1948; Davidson, 1976; McGee, 1980; Flyger and Gates, 1982; Forrester, 1992). Considerably less is known about helminths of flying squirrels, particularly those of *G. volans* from southeastern North America. The southern flying squirrel is host to at least 7 helminth species, a depauperate number compared with other North American tree squirrel species (Rausch and Tiner 1948; Parker 1968; Davidson, 1976). Price (1928) described *S. thompsoni* from southern flying squirrels trapped in Virginia, and Chandler (1947) reported finding the acanthocephalan *Moniliformis clarki* in *G. volans* collected in Florida. Rausch and Tiner (1948) found *C. bifurcatum*, *Capillaria* sp., and *Enterobius sciuri* in southern flying squirrels from the North Central States, and Read (1949) described *Capillaria* sp. of Rausch and Tiner (1948) as *C. americana*. Eckerlin (1974) reported *S. robustus* and *Catenotaenia pusilla* in southern flying squirrels from Connecticut. Patrick (1991a) described the spatial distribution of *S. robustus* and *C. americana* in the small intestine of *G. volans* and tested for ecological release in the parasite community of this host.

Compared with flying squirrels, other sciurids are infected with more species of helminths. For example, gray squirrels from the southeast are parasitized by up to 20 different intestinal helminths including 2 trematode, 3 cestode, and 15 nematode species (Davidson, 1976). This difference may be explained, in part, by the fact that flying squirrels spend less time on the ground than other tree squirrels and might have less contact with soil stages of some nematodes. Differences in diet may explain the lack of cestodes and trematodes.

Of the 7 known gastrointestinal helminths of the southern flying squirrel, only 3 nematodes and 1 acanthocephalan species were found in the squirrels trapped at Fort Stewart. In addition, 1 squirrel was infected with a cestode that was unidentifiable because of poor condition. The most abundant helminth, *S. thompsoni*, occurred in over 90% of the squirrels examined. This finding is consistent with that of Eckerlin (1974), who recorded *S. thompsoni* in 100% of *G. volans* from Florida. Rausch and Tiner (1948) observed this parasite in all northern flying squirrels but none in southern flying squirrels from the North Central States. Similarly, Patrick (1991b) did not find *S. thompsoni* in *G. volans* from Pennsylvania. The parasite was also observed in *G. volans* and *G. sabrinus* from Virginia (Price, 1928, Pagels et al., 1990) and *G. volans* from Connecticut (Eckerlin, 1974). The prevalence and intensity of *S. thompsoni* in gray and fox squirrels from southeastern North America is low compared with the numbers we recorded for southern

flying squirrels from Georgia (Davidson, 1976; Conti et al., 1984; Coyner et al., 1996). For example, Davidson (1976) found 1–34 *S. thompsoni* in 5% of gray squirrels trapped at several localities in southeastern North America. *S. thompsoni* has not been previously reported in any sciurid from Georgia.

The second most common helminth, observed at low intensity in 24% of the flying squirrels, was *S. robustus*. Similarly, this parasite infects 29% of *G. volans* in Florida (Eckerlin, 1974) but its prevalence may be as high as 100% in *G. volans* from Pennsylvania (Patrick, 1991a, b). The parasite is found at high intensity in over 50% of gray squirrels in the southeast (Davidson, 1976; Conti et al., 1984) and over 80% of Sherman's fox squirrels (*S. niger shermani*) in Florida (Coyner et al., 1996).

We failed to observe the cecal parasite *E. sciuri*. This was somewhat unexpected because the parasite is reported to infect gray squirrels in Georgia (Davidson, 1976) and is common in *G. volans* from other localities (Rausch and Tiner, 1948).

We found 1 specimen of the acanthocephalan *M. clarki*. This is a new state record for tree squirrels from Georgia. In the southeast, *M. clarki* has been reported in *G. volans* from Florida (Chandler, 1947), gray squirrels from Alabama, Florida, and South Carolina (Chandler, 1947; Davidson, 1976; Conti et al., 1984), and fox squirrels from Florida (Chandler, 1947; Coyner et al., 1996).

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