

Strongyloides robustus and the Northern Sympatric Populations of Northern (*Glaucomys sabrinus*) and Southern (*G. volans*) Flying Squirrels

Authors: Pauli, Jonathan N., Dubay, Shelli A., Anderson, Eric M., and Taft, Stephen J.

Source: Journal of Wildlife Diseases, 40(3) : 579-582

Published By: Wildlife Disease Association

URL: <https://doi.org/10.7589/0090-3558-40.3.579>

The BioOne Digital Library (<https://bioone.org/>) provides worldwide distribution for more than 580 journals and eBooks from BioOne's community of over 150 nonprofit societies, research institutions, and university presses in the biological, ecological, and environmental sciences. The BioOne Digital Library encompasses the flagship aggregation BioOne Complete (<https://bioone.org/subscribe>), the BioOne Complete Archive (<https://bioone.org/archive>), and the BioOne eBooks program offerings ESA eBook Collection (<https://bioone.org/esa-ebooks>) and CSIRO Publishing BioSelect Collection (<https://bioone.org/csiro-ebooks>).

Your use of this PDF, the BioOne Digital Library, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Digital Library content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne is an innovative nonprofit that sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

***Strongyloides robustus* and the Northern Sympatric Populations of Northern (*Glaucomys sabrinus*) and Southern (*G. volans*) Flying Squirrels**

Jonathan N. Pauli,^{1,2,3} Shelli A. Dubay,^{1,4,5} Eric M. Anderson,² and Stephen J. Taft¹ ¹ Department of Biology, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin 54481, USA; ² Department of Wildlife, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin 54481; ³ Current address: Department of Zoology and Physiology, University of Wyoming, PO Box 3166, Laramie, Wyoming 82071, USA; ⁴ Current address: Waterloo Wildlife Office, Michigan Department of Natural Resources, 13578 Seymour Road, Grass Lake, Michigan 49240, USA; ⁵ Corresponding author: Shelli Dubay (email: dubaysa@michigan.gov)

ABSTRACT: Within North America, northern (*Glaucomys sabrinus*) and southern (*Glaucomys volans*) flying squirrels occupy distinct ranges with limited overlap. Sympatry in northern latitudes coincides with northern hardwood vegetation from Minnesota to New England. *Strongyloides robustus* is an intestinal parasite that infects both species but appears to be deleterious only to northern flying squirrels. As a result, *S. robustus* could be a critical determinant of flying squirrel population characteristics in at least some areas of sympatry. However, cold weather could potentially limit the distribution of *S. robustus* in northern climates. Therefore, we assessed fecal samples from both flying squirrel species to determine the presence of the nematode in Wisconsin. *Strongyloides robustus* was found in 12 flying squirrel scat samples and infected 52% of southern flying squirrels and 11% of northern flying squirrels. Prevalence of *S. robustus* infection for northern flying squirrels was substantially lower than previously reported from more southern regions. This is the northernmost documentation of *S. robustus* in flying squirrels and the first documentation of *S. robustus* parasitizing flying squirrels in Wisconsin.

Key words: Flying squirrels, *Glaucomys sabrinus*, *Glaucomys volans*, sciuridae, *Strongyloides robustus*, Strongyloididae, sympatry, Wisconsin.

Two flying squirrel species are recognized in North America: the northern, *Glaucomys sabrinus*, and southern, *Glaucomys volans* (Dolan and Carter, 1977; Wells-Gosling and Heaney, 1984). As their common names imply, the two species have distinct ranges with only limited overlap. They are ecologically similar and are irregularly sympatric in the southern Appalachians and throughout a relatively narrow band of northern hardwood vegetation from Minnesota eastward through south-

ern Canada and New England (Muul, 1968; Weigl, 1978). Weigl et al. (1999) suggested that regions of overlap supporting roughly equal numbers of both species have low and fluctuating flying squirrel populations (Weigl et al., 1999), although the source of population oscillations is unknown.

In overlap regions, northern and southern species seem to remain segregated within microenvironments (Weigl, 1978). Greater aggression of southern flying squirrels, differential adaptation to altitude and climate, vegetation preferences, diet availability, and differential susceptibility to parasitic diseases have been proposed to explain species segregation (Muul, 1968; Weigl, 1978).

Strongyloides robustus is an intestinal nematode that infects both species, but infection is more prevalent in the southern species (Wetzel and Weigl, 1994). Eggs are produced within the hosts' gastrointestinal tract, are shed in feces, and develop into larvae, which, after two molts, transform into an infective form (Anderson, 1992). *Strongyloides robustus* is pathogenic to most sciurids and can cause severe hemorrhagic enteritis (Davidson, 1976).

Strongyloides robustus might limit northern flying squirrels in areas of overlap because northern flying squirrels represent a susceptible "naïve" host compared with southern flying squirrels (Weigl, 1968; Weigl et al., 1999). This postulate was based on observations that when both species were infected with *S. robustus*, northern flying squirrels were detrimentally af-

fects by infection and experienced high rates of mortality, whereas southern flying squirrels appeared unaffected by infection and even produced several litters (Weigl, 1968). Although *S. robustus* is a significant cause of mortality in captive northern flying squirrels, there is little information on the influence this parasite might have on the ecology of flying squirrels and its role in mediating competition between the two species in regions of sympatry.

Rausch and Tiner (1948) documented *S. robustus* in three species of tree squirrels in the Upper Great Lakes region: red squirrels (*Tamiasciurus hudsonicus*), gray squirrels (*Sciurus carolinensis*), and fox squirrels (*Sciurus niger*). However, they did not detect *S. robustus* in either species of flying squirrel. Previous studies in more southern regions have shown that harsh winters markedly decrease the probability of *S. robustus* survival (Wetzel and Weigl, 1994). Therefore, it was conceivable that at higher latitudes, *S. robustus* might not even exist in flying squirrels. The goal of this study was to assess the presence, species distribution, and intensity of *S. robustus* in both flying squirrel species inhabiting the 83-ha Schmeeckle Reserve located in Portage County, Wisconsin, USA (89°34'3"W, 44°32'25"N).

The reserve lies in a vegetative tension zone separating the southern prairie-forest region from the northern hardwood region (Curtis and McIntosh, 1951). Primary overstory vegetation includes red maple (*Acer rubrum*), red oak (*Quercus rubra*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), hop-hornbeam (*Caprinus caroliniana*), white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), and red pine (*Pinus resinosa*).

Fecal samples from free-ranging flying squirrels were collected from sympatric populations located in Schmeeckle Reserve. Three sets of flying squirrel scat samples were used: seventeen scat samples were obtained in 1994 (seven northern and 10 southern flying squirrels of unknown sex), five samples were collected in

2000 (two northern, one each from a male and female, and three southern flying squirrels, all male), and eight samples were collected in 2002 (eight southern flying squirrels, one female and seven males). Irrespective of the year, all scat samples were collected from flying squirrels live-trapped between 1 September and 30 November and preserved in 10% formalin.

Three scat pellets were randomly selected from each sample and prepared with the use of a modified formalin-ethyl acetate sedimentation technique (Ritchie, 1948; Pritchard and Kruse, 1982). Scat pellets were broken apart and strained through double-layered wide-mesh cheesecloth with 10% formalin. The cheesecloth containing large unstrained material was discarded. Fecal material suspended in solution was centrifuged at $1,500 \times G$ for 1 min. The sediment was resuspended in 10 ml of fresh formalin. Ethyl acetate (3 ml) was added to the suspension and shaken for 1 min. The solution was recentrifuged at $1,380 \times G$ for 1 min, and three drops of iodine were added to the sediment. This was placed on a slide and examined by light microscopy for eggs and larvae of *S. robustus*, identified by size and morphologic criteria (Chandler, 1942; Eckert, 1974; Wetzel, 1992; Bartlett, 1995); eggs in each sample were counted. Prevalences of infection for northern and southern flying squirrels were compared by Fisher's exact test (Zar, 1996). Pellets that were not microscopically screened for parasites were dried and weighed to estimate the mean mass of flying squirrel fecal pellets.

Strongyloides robustus was present in 40% of flying squirrel scat samples (Table 1). Prevalence was significantly higher in southern flying squirrels than in northern flying squirrels ($P=0.049$, Fisher exact test). Numbers of eggs per fecal pellet for flying squirrels was highly variable (Table 1).

Prevalence of southern flying squirrels infected with *S. robustus* varied from 24% to 100% in more southern portions of their range (Patrick, 1991; Pung et al., 2000). Weigl et al. (1999) reported 80% preva-

TABLE 1. Prevalence and intensity of *Strongyloides robustus* eggs/fecal pellet from nine northern (*Glaucomys sabrinus*) and 21 southern (*Glaucomys volans*) flying squirrels inhabiting central Wisconsin.

Host	Prevalence (%)	Intensity		
		\bar{x}	SD	Range
<i>Glaucomys sabrinus</i>	11	16 ^a	NA ^a	NA ^a
<i>G. volans</i>	52	14	13.5	1–20
Total	40	14	12.9	1–20

^a Mean, standard deviation, and range were incalculable because $n=1$.

lence in northern flying squirrels in North Carolina and Tennessee (USA). Our estimated prevalence of *S. robustus* infection for southern flying squirrels is similar to prevalence of infection documented at lower latitudes. Prevalence of infection in northern flying squirrels in central Wisconsin appears to be substantially lower than reported elsewhere (Weigl et al., 1999).

Previous research has shown that *S. robustus* egg counts are highly and significantly correlated with the number of adult *S. robustus* parasitizing flying squirrels (Wetzel, 1992). Thus, fecal egg counts for *S. robustus* provide at least a relative index of worm abundance in both species of flying squirrels. In North Carolina and Tennessee, egg counts for southern flying squirrels exceeded 1,000 eggs/g, and approximately 60% of infected northern flying squirrels had intensities exceeding 500 eggs/g (Weigl et al., 1999). Given a mean mass for one flying squirrel fecal pellet of 0.10 g (SD=0.024, $n=22$) and given that each pellet had an average of 14 eggs, our reported intensities appeared to be considerably lower than those reported by Weigl et al. (1999).

Strongyloides robustus is susceptible to cold temperatures (Wetzel and Weigl, 1994), and its abundance might be reduced in northern flying squirrels in the Upper Great Lake region because of decreased survival from exposure to severe and prolonged winters. Survival of *S. robustus* outside of its host in cold climates presents a special challenge (Wetzel and Weigl, 1994). Both species of flying squir-

rels aggregate during the winter, but the southern flying squirrel forms large aggregations of up to 50 individuals (Merritt et al., 2001). Although these aggregations might both decrease thermoregulatory costs and serve a social function (Merritt et al., 2001), such aggregations could also create a more suitable thermal environment for *S. robustus* survival and dispersal. Furthermore, flying squirrels often line nest sites with various kinds of organic material. Moist organic material could provide enhanced microhabitat for parasites and increase *S. robustus* transmission. In contrast, although not optimal for winter survival, northern flying squirrels will nest in open-faced leaf nests known as drays (Jackson, 1961). In sympatric areas, where nest site competition with southern flying squirrels is high, winter use of drays by northern flying squirrels might be particularly prevalent (Jackson, 1961). Therefore, the lower *S. robustus* infection frequency in northern flying squirrels reported herein might result from *S. robustus* being exposed to severe winter weather because of the tendency for northern flying squirrels to use drays.

Weigl et al. (1999) suggested that *S. robustus* and the southern flying squirrel have had a longer association than *S. robustus* and the northern flying squirrel. Although unproven, this is reasonable because the life cycle of *S. robustus* seems particularly suited to the natural history of southern flying squirrels, which, unlike the northern flying squirrels, occur at lower latitudes and altitudes, strongly prefer tree cavities for nest sites, and defecate within nesting cav-

ities (Wetzel and Weigl, 1994). Feces deposited in nest cavities create an ideal microenvironment for *Strongyloides* eggs to develop and infect southern flying squirrels. Infection of northern flying squirrels appears to occur when they take over abandoned or secondary southern flying squirrel nests (Wetzel and Weigl, 1994).

This is the first documentation of *S. robustus* in flying squirrels from Wisconsin and the northernmost documentation of *S. robustus* infecting either species of flying squirrels. Because infection of northern flying squirrels by *S. robustus* possibly is more deleterious than in southern flying squirrels, it could play a role in variability of flying squirrel populations and in segregation of northern and southern flying squirrels in the northernmost portions of their overlapping range.

We thank the University of Wisconsin-Stevens Point for funding this study through the Student Research Fund and to the Student Chapter of the Wildlife Society for helping to procure samples.

LITERATURE CITED

- ANDERSON, R. C. 1992. Nematode parasites of vertebrates: Their development and transmission. CAB International, Wallingford, UK, 578 pp.
- BARTLETT, C. M. 1995. Morphology, homogonic development, and lack of a free-living generation in *Strongyloides robustus* (Nematoda, Rhabditoidea), a parasite of North American sciurids. *Folia Parasitologica* 42: 102–114.
- CHANDLER, A. C. 1942. Helminths of tree squirrels in southeast Texas. *Journal of Parasitology* 28: 135–140.
- CURTIS, J. T., AND R. P. MCINTOSH. 1951. An upland forest continuum in the prairie-forest border of Wisconsin. *Ecology* 32: 476–496.
- DAVIDSON, W. R. 1976. Endoparasites of selected populations of gray squirrels (*Sciurus carolinensis*) in the southeastern United States. *Proceedings of the Helminthological Society of Washington* 43: 211–216.
- DOLAN, P. G., AND D. C. CARTER. 1977. *Glaucomys volans*. *Mammalian Species* 78: 1–6.
- ECKERLIN, R. P. 1974. Studies on the life cycle of *Strongyloides robustus* Chandler, 1942, and a survey of the helminths of Connecticut sciurids. PhD Dissertation, University of Connecticut, Storrs, Connecticut, 116 pp.
- JACKSON, H. H. T. 1961. *Mammals of Wisconsin*. The University of Wisconsin Press, Madison, Wisconsin, 504 pp.
- MERRITT, J. F., D. A. ZEGERS, AND L. R. ROSE. 2001. Seasonal thermogenesis of southern flying squirrels (*Glaucomys volans*). *Journal of Mammalogy* 82: 51–64.
- MUUL, I. 1968. Behavioral and physiological influences on the distribution of the flying squirrel, *Glaucomys volans*. *Miscellaneous Publications of the Museum of Zoology, University of Michigan* 134: 1–66.
- PATRICK, M. J. 1991. Occurrence of *Strongyloides robustus* (Rhabditata: Strongyloidea) in squirrels (Sciuridae) from Indiana County, Pennsylvania. *Journal of the Pennsylvania Academy of Science* 65: 48–50.
- PRITCHARD, M. P., AND G. O. W. KRUSE. 1982. The collection and preservation of animal parasites. University of Nebraska Press, Lincoln, Nebraska, 141 pp.
- PUNG, O. J., L. A. DURDEN, M. J. PATRICK, T. CONYERS, AND L. R. MITCHELL. 2000. Ectoparasites and gastrointestinal helminths of southern flying squirrels in southeast Georgia. *Journal of Parasitology* 86: 1051–1055.
- RAUSCH, R., AND J. D. TINER. 1948. Studies on the parasitic helminths of the North Central States. *American Midland Naturalist* 39: 728–747.
- RITCHIE, L. S. 1948. An ether sedimentation technique for routine stool examinations. *Bulletin of the US Army Medical Department* 8: 326.
- WEIGL, P. D. 1968. The distribution of the flying squirrels *Glaucomys volans* and *G. sabrinus*: An evaluation of the competitive exclusion idea. PhD Dissertation, Duke University, Durham, North Carolina, 246 pp.
- . 1978. Resource overlap, interspecific interactions and the distribution of the flying squirrels, *Glaucomys volans* and *G. sabrinus*. *American Midland Naturalist* 100: 83–96.
- , T. W. KNOWLES, AND A. C. BOYNTON. 1999. The distribution and ecology of the northern flying squirrel, *Glaucomys sabrinus coloratus*, in the southern Appalachians. *North Carolina Wildlife Resources Commission Nongame and Endangered Wildlife Program, Division of Wildlife Management, Raleigh, North Carolina*, 93 pp.
- WELLS-GOSLING, N., AND L. R. HEANEY. 1984. *Glaucomys sabrinus*. *Mammalian Species* 229: 1–8.
- WETZEL, E. J. 1992. The effects of temperature on the in vitro development and behavior of *Strongyloides robustus*: Ecological implications. MS Thesis, Wake Forest University, Winston-Salem, North Carolina, 45 pp.
- , AND P. D. WEIGL. 1994. Ecological implications for flying squirrels (*Glaucomys* spp.) of effects of temperature on the in vitro development and behavior of *Strongyloides robustus*. *American Midland Naturalist* 131: 43–54.
- ZAR, J. H. 1996. *Biostatistical analysis*, 3rd Edition. Prentice Hall, Upper Saddle River, New Jersey, 121 pp.

Received for publication 2 June 2003.