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Evaluation of Fox-chasing Enclosures as Sites of Potential Introduction and Establishment of *Echinococcus multilocularis*

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ABSTRACT: Following detection of *Echinococcus multilocularis* in red foxes (*Vulpes vulpes*) illegally imported into South Carolina (USA) for release in fox-chasing enclosures, a survey for *E. multilocularis* was conducted in four enclosures in Georgia (USA) and six enclosures in South Carolina. Survey methods included examination of potential small mammal intermediate hosts (n = 390) for *E. multilocularis* larvae, examination of fox and coyote (*Canis latrans*) scats (n = 59) for taeniid eggs, and examination of one possible canine definitive hosts for adult *E. multilocularis*. All intermediate and definitive hosts examined were negative for *E. multilocularis* and taeniid eggs were not recovered from fox and coyote fecal samples. Thus, *E. multilocularis* may not yet be established in fox-chasing enclosures in Georgia and South Carolina. Despite the failure to demonstrate *E. multilocularis* in the fox-chasing enclosures surveyed, translocation of wild canids from known enzootic regions should be discouraged because *E. multilocularis* is known to be ecologically adaptable and because contact with potentially infected definitive hosts during translocation is a public health risk.

Key words: *Echinococcus multilocularis*, fox-chasing enclosures, survey, host translocation.

In recent years fox hunting with hounds has become restricted because of increased losses of suitable hunting areas and decreased public tolerance of trespass by dogs. In addition, increased white-tailed deer (*Odocoileus virginianus*) populations have confounded this sport since hounds often pursue deer. As a result of these constraints, a number of fox-chasing enclosures, areas averaging 250 ha and enclosed with fox-proof fencing, have been constructed throughout the United States; all southeastern states now have fox-chasing enclosures. Animals to stock these enclosures are acquired from different sources, depending on individual state regulations. Several states allow the importation of foxes and coyotes (*Canis latrans*) from other parts of the country; others require that the animals originate from within the state. Additionally, some states prohibit the release of coyotes into fox-chasing enclosures.

One major concern has been the possible introduction of the cestode *Echinococcus multilocularis* into new regions of the country via translocation and release of infected animals in enclosures (Rausch, 1986; Davidson and Nettles, 1988). In 1989, coyotes and red foxes (*Vulpes vulpes*) illegally imported into South Carolina (USA) were confiscated by officials with the South Carolina Wildlife and Marine Resources Department and the United States Fish and Wildlife Service and necropsied by Southeastern Cooperative Wildlife Disease Study (SCWDS) personnel at The University of Georgia, Athens, Georgia (USA). In addition to other canid parasites, adult *E. multilocularis* were found in three of 44 red foxes (Davidson et al., 1992). Based on records obtained during the investigation of this case, hundreds of foxes from *Echinococcus*-enzootic areas had been supplied to fox-chasing enclosures in 25 states; thus infected foxes already may have been released into southeastern fox-chasing enclosures. Because of these findings, we initiated a survey of fox-chasing enclosures to determine whether *E. multilocularis* had become established in the southeastern United States.

From 10 December 1991 to 19 May 1992, four fox-chasing enclosures in Georgia (Lanier, Madison, Mitchell, and Pickens counties) and six fox-chasing enclosures in South Carolina (Florence,

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Georgetown, and Horry counties) known to have received or stocked imported foxes from *Echinococcus*-enzootic areas in the past (Davidson et al., 1992) were surveyed for the presence of *E. multilocularis*. Small mammal intermediate hosts were trapped with Sherman live traps (H.B. Sherman Traps, Inc., Tallahassee, Florida, USA) baited with sunflower seeds and a peanut butter and peanut oil mixture, and selectively placed near obvious rodent sign such as runways and holes. Captured animals were euthanatized with CO_2, necropsied, and examined macroscopically for the presence of larval *E. multilocularis*. Tissues with suspect lesions were fixed in 10% neutral buffered formalin, embedded in paraffin, sectioned, stained using hematoxylin-eosin (HE) or periodic-acid-schiff (PAS), and examined microscopically for evidence of multilocular cysts and larvae (Rausch, 1967; Leiby et al., 1970).

Maximum prevalence of infection was defined as the upper limit of a 95% confidence interval constructed around the number of individuals in the population that were infected with *E. multilocularis*, assuming a binomial distribution (Steel and Torrie, 1980) and using only those species or genera known to serve as intermediate hosts (Table 1) (Leiby, 1965; Leiby et al., 1970; Rausch et al., 1990). We also assumed all rodents were equally susceptible to *E. multilocularis* infection, and a 100% sensitivity in detection of hydatid cysts.

Concurrent with small mammal trapping, the entire road system and fenceline of enclosures were surveyed daily during field operations for the presence of fox and coyote feces. Feces were placed in a plastic bag and frozen at −29 C. Collected feces from each enclosure were examined for taeniid eggs by formalin-ether sedimentation and sodium nitrate fecal flotation (Ash and Orihel, 1987).

Enclosure owners were unwilling to provide live foxes or coyotes for examination. Consequently, any foxes and coyotes found dead in the enclosures were collected and examined for adult *E. multilocularis*. The stomach and small intestine were excised, opened longitudinally, scraped, and washed through a 100-mesh screen. The retained intestinal contents were examined microscopically (10 to 40×) for parasites (Davidson et al., 1992).

TABLE 1. Species composition and number of small mammals collected in fox-chasing enclosures in Georgia and South Carolina.

Species	Georgia	South Carolina	Total
Blarina carolinensis[a]	7	47	54
Microtus pinetorum[a]	0	8	8
Mus musculus[a]	6	69	75
Napaeozapus insignis	2	0	2
Neotoma floridanus[a]	5	0	5
Ochrotomys nuttalli	3	3	6
Oryzomys palustris	1	10	11
Peromyscus gossypinus[a]	13	15	28
Peromyscus leucopus[a]	7	0	7
Peromyscus polionotus[a]	8	0	8
Reithrodontomys humulis	5	31	36
Sigmodon hispidus[a]	40	106	146
Tamias striatus	4	0	4
Total	101	289	390

[a] Species or genera known to serve as intermediate hosts of *E. multilocularis*.

Collectively, 390 small mammals were caught and examined for larval *E. multilocularis*; 101 were from Georgia and 289 from South Carolina. Of these, 331 (85%) of 390 animals belonged to species or genera known to serve as intermediate hosts (Table 1). Most animals captured were cotton rats (*Sigmodon hispidus*) (37%), followed by house mice (*Mus musculus*) (19%), southern short-tailed shrews (*Blarina carolinensis*) (14%), white-footed mice (*Peromyscus* spp.) (11%), and eastern harvest mice (*Reithrodontomys humulis* (9%) (Table 1). All animals were negative for larval *E. multilocularis*. However, three cotton rats, a house mouse, and a cotton mouse (*P. gossypinus*) from Georgia and five cotton rats from South Carolina were infected with *Taenia* spp. larvae. Not all *Taenia* cysticerci could be identified to species; however, most were *T. crassiceps*. Infections of *T. mustelae* were noted in a

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cotton mouse and a house mouse from enclosures in Georgia.

Fifty-nine canid fecal samples were collected and examined including 15 samples from three fox-chasing enclosures in Georgia and 44 samples from five fox-chasing enclosures in South Carolina. Taeniid eggs were not recovered from any fecal samples by either formalin-ether sedimentation or sodium nitrate flotation. Hookworm (*Ancylostoma* sp.) eggs were recovered from canid feces collected in Georgia fox-chasing enclosures. Hookworm, roundworm (*Toxocara* spp. or *Toxascaris leonina*), and whipworm (*Trichuris* spp.) eggs were recovered from fecal samples collected in South Carolina enclosures.

Only one definitive host, a coyote from Georgia, was available for examination. Adult *E. multilocularis* were not found in the stomach or intestinal contents of the animal.

Based on these results, *E. multilocularis* was not present at a high prevalence, if at all, in either small mammal or definitive host populations in fox-chasing enclosures in Georgia or South Carolina, despite strong circumstantial evidence that infected red foxes probably had been introduced previously (Davidson et al., 1992). Based on the number of small mammals captured in each state and assuming equal susceptibility and exposure among species, which may not be true, the maximum prevalence of the tapeworm in fox-chasing enclosures in Georgia and South Carolina would be 3% and 1%, respectively, with an overall maximum prevalence of 1% (95% confidence limit) (Steel and Torrie, 1980).

This estimate of 1% maximum prevalence in fox-chasing enclosures in Georgia and South Carolina is considerably lower than prevalence estimates among major intermediate hosts collected in enzootic locations in the northcentral United States. Leiby et al. (1970) reported 197 (5.9%) of 3,335 deer mice (*Peromyscus maniculatus*) from North Dakota infected with *E. multilocularis*, and Leiby and Kritsky (1974) found an average yearly prevalence in deer mice of 4.4%.

The reasons for the apparent absence of *E. multilocularis* are not known, since *E. multilocularis* is extremely adaptive and is biologically suited to exist in diverse ecological settings (Rausch, 1986). Until a biological mechanism precluding the establishment of *E. multilocularis* is demonstrated, the probability of establishment following release of infected animals into this region still should be considered high. Furthermore, importation of infected foxes and coyotes poses a significant public health risk since eggs that are directly infectious to humans may be shed in fox and coyote feces. For these reasons, any future translocation and release of known host species from *E. multilocularis* enzootic areas should be discouraged.

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