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HELMINTH PARASITES OF INTERMINGLING AXIS DEER, WILD SWINE AND DOMESTIC CATTLE FROM THE ISLAND OF MOLOKAI, HAWAII

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ABSTRACT: Helminth infections of axis deer (*Cervus axis*), wild swine (*Sus scrofa*) and domestic cattle (*Bos taurus*) were studied among intermingling herds on the Puu-O-Hoku Ranch, Molokai, Hawaii. Twenty-four species of helminths were collected from the 10 deer, 10 swine and 10 cattle. *Capillaria bovis*, *Cooperia punctata*, *Haemonchus contortus* and *Trichostrongylus axei* infected both axis deer and cattle, whereas *Gongylonema pulchrum* infected both axis deer and wild swine. None of the species of helminths occurred in both wild swine and cattle nor was any species found in all three hosts. Wild swine and domestic cattle supported separate and distinct helminth communities. In contrast, the helminth community of axis deer appeared to be derived from the helminth communities of cattle and wild swine and consisted only of those species capable of parasitizing either a broad range of ruminants or many mammalian taxa.
Key words: Helminth parasites, axis deer, *Cervus axis*, wild swine, *Sus scrofa*, cattle, *Bos taurus*, Hawaii, survey.

INTRODUCTION

A lack of information about possible disease interactions between feral livestock, domestic livestock and wildlife has been acknowledged (Larsen, 1982). However, a few studies have addressed parasite transmission among various wild and domestic animals. Work completed in the southeastern United States has shown that helminths harbored by white-tailed deer (*Odocoileus virginianus*) generally are distinct from those of feral and domestic livestock (Prestwood et al., 1975, 1976).

A unique situation exists on Molokai, Hawaii since axis deer (*Cervus axis*), wild swine (*Sus scrofa*) and domestic cattle (*Bos taurus*) along with their respective parasites have been perpetuated in a relatively confined ecologic system. Eight axis deer were released on Molokai in 1869 with no subsequent introductions reported (Tomich, 1986). Swine were released on the Hawaiian islands by Polynesian settlers about the 2nd century, but other swine have been introduced to the islands at various times (Giffin, 1978; Tomich, 1986). Cattle have been introduced and removed from the Puu-O-Hoku Ranch, Molokai, Hawaii on two separate occasions (Essey et al., 1981). Thus, the intermittent introduction of cattle and swine and the intermingling of axis deer, wild swine and domestic cattle on Puu-O-Hoku Ranch suggested a potential for examination of the exchange of helminth species among these three hosts.

MATERIALS AND METHODS

Puu-O-Hoku Ranch (156°44'W, 21°9'N), located on the eastern side of Molokai (Hawaii, USA), is bordered by the Molokai Forest Reserve and the Pacific Ocean. The ranch consists of 2,800 ha of pasture dissected by eight deep ravines that support various successional stages of rain forest. Pastures consist of lush, high grass areas on ridge tops. Most of the forested areas support mature stands of several introduced tree species. There is virtually no shrub community beneath the high canopy of the mature forest stands. Observations during this and other concurrent studies (Essey et al., 1981) disclosed that cattle and axis deer often frequented the same pastures at night, while wild swine and axis deer utilized the rain forests during the day. Cattle and wild swine were observed utilizing the same portions of the ranch less frequently during the period of this study.

During June 1980, five adult (>1 yr) and five fawn (2.5 to 6 mo) axis deer were shot at night. Ten wild swine were captured alive with the aid of hunting dogs during July and August 1980, and subsequently killed. Viscera from 10 domestic cattle shipped from Puu-O-Hoku Ranch were obtained at an Oahu abattoir during the December 1980 depopulation of cattle from the ranch. Standard necropsy procedures, parasitologic techniques and histologic techniques were used for each host and have been described elsewhere (Nettles, 1981; McKenzie, 1982; Smith et al., 1982). Serum samples were collected from wild swine for detection of *Trichinella spiralis* antibody by using enzyme-linked immunosorbent assay (Food Safety Inspection Service Laboratory, FSQS, USDA, Beltsville, Maryland 20705, USA). A paired *t*-test was used to detect differences between helminth infections [$\log_{10}(N + 1)$ transformed data on number of helminth individuals] occurring in more than one species of host and between age classes of axis deer. Representative specimens of helminths recovered during this project have been deposited in the U.S. National Parasite Collection (Animal Parasitology Institute, USDA, Beltsville, Maryland 20705, USA; accession numbers 77201–77228). Data on helminth infections in individual animals from this study is available (McKenzie, 1982).

RESULTS

Twenty-four species of helminths were collected from the 10 axis deer, 10 wild swine and 10 cattle sampled (Table 1). Helminths recovered included: one species of cestode and six species of nematodes from axis deer, 13 species of nematodes from wild swine, and one species of cestode and eight species of nematodes from cattle. All animals were infected with at least one species of helminth. Axis deer fawns had seven species of helminths compared to only two species (*Cooperia punctata* and *Gongylonema pulchrum*) in adult axis deer (Table 2). The total number of helminths in axis deer fawns was significantly higher than in adults ($P < 0.005$). *Trichostrongylus axei* accounted for 90% of the total number of helminth individuals recovered in axis deer fawns whereas *G. pulchrum* accounted for 99% of the total number of helminth individuals recovered from adult deer. Four species of nematodes (*Capillaria bovis*, *C. punctata*, *Haemonchus contortus* and *T. axei*) occurred in both axis deer and cattle. The intensity of infection by each of these species was higher in cattle than in axis deer ($P < 0.05$). A single species of nematode (*G. pulchrum*) occurred in both axis deer and wild swine. The intensity of *G. pulchrum* infection was higher in axis deer than in wild swine ($P < 0.05$). None of the species of helminths occurred in both wild swine and cattle, nor was any species of helminth found in all three hosts. Serologic tests for antibody against *T. spiralis* were uniformly negative.

Few gross or microscopic lesions attributable to parasitism were noted among the animals examined. Granulomatous inflammation of perirenal tissues, lungs and lymph nodes was associated with infection by *Stephanurus dentatus* in wild swine. A mild eosinophilic peribronchitis or an effusion of eosinophils within the aveolar spaces were often noted upon histopathologic examination of lungs from wild swine infected with *Metastrongylus* spp. lungworms. These histopathologic findings were inconclusive, however, because of the presence of concurrent *S. dentatus* and *Mycobacterium bovis* infections in the lungs of the more heavily parasitized animals (Essey et al., 1981). Neither gross nor microscopic lesions attributable to parasitism were detected in axis deer or cattle.

DISCUSSION

The 24 species of helminths identified in this study were representative of those previously reported from axis deer, wild swine and domestic cattle from the Hawaiian island archipelago (Alicata, 1969), although some new geographic and host records were established for these hosts specifically on the island of Molokai. Prior studies involving these hosts on the island of Molokai have disclosed only *C. punctata* in axis deer (Ash, 1961) and *Stephanofilaria stilesi* in cattle (Cuckler and Alicata, 1943). The review of parasites of swine from the Hawaiian islands by Alicata

TABLE 1. Helminth parasites of axis deer, wild swine and domestic cattle from Puu-O-Hoku Ranch, Maui County, Molokai, Hawaii.

Helminth	Axis deer (n = 10)	Wild swine (n = 10)	Domestic cattle (n = 10)
Cestoda			
Monezia benedeni	10/1/1[a]	—	—
Wyominia tetoni	—	—	10/1/1
Nematoda			
Ascrops dentata	—	10/1/1	—
Capillaria bovis	20/2/2	—	30/34/79
Ceratospira opthalmica	—	30/10/25	—
Cooperia pectinata	—	—	40/1,077/3,685
Cooperia punctata	60/7/17	—	40/1,903/5,230
Dictyocaulus viviparus	—	—	90/3/7
Eucyathostomum sp.	—	20/17/21	—
Gongylonema pulchrum	60/78/143	100/7/16	—
Haemonchus contortus	10/34/34	—	100/271/840
Metastrongylus apri	—	80/46/204	—
Metastrongylus pudentotectus	—	70/31/118	—
Metastrongylus sp.[b]	—	40/2/2	—
Oesophagostomum dentatum	—	100/297/962	—
Oesophagostomum quadrispinulatum	—	100/27/83	—
Oesophagostomum radiatum	—	—	50/52/86
Ostertagia ostertagi	—	—	100/2,413/9,668
Physocephalus sexalatus	—	20/3/4	—
Raillietostrongylus samoensis	—	100/1,514/2,315	—
Stephanurus dentatus	—	100/30/72	—
Trichostrongylus axei	30/315/778	—	50/802/1,770
Trichuris suis	—	20/2/2	—
Trichuris sp.	30/4/7	—	—

[a] Figures in columns are prevalence (%)/intensity/maximum number per host.
[b] Fragments of either *M. apri* or *M. pudentotectus*.

(1969) does not contain any records for the island of Molokai.

The helminth communities of wild swine and cattle on Molokai were comprised of species often infecting these hosts in the Hawaiian islands and elsewhere (Alicata, 1969; Soulsby, 1971). The only exceptions were the occurrence of several specimens of *Ceratospira opthalmica* in three wild swine and a single scolex tentatively identified as *Wyominia tetoni* in one cow. *Ceratospira opthalmica* infects the eyes of tropical birds, and its presence in wild swine was attributed to the consumption of birds as was evident from the presence of feathers in the intestinal contents. The origin of *Wyominia tetoni* is uncertain; however, some of the original herd of Charlais cattle moved to Molokai after 1957 had been ranged in Canada where *W. tetoni* has been reported from bighorn sheep (*Ovis canadensis*) (Uhazy and Holmes, 1971; Colwell et al., 1975).

In contrast to the typical helminth communities of wild swine and domestic cattle, the helminth community of axis deer appears to have been derived entirely from the helminth communities of other hosts. All of the species of helminths recovered from axis deer are frequent parasites of either cattle or swine in the Hawaiian islands (Alicata, 1969), and most were recovered from cattle or wild swine during this study. Five of these helminths (*Monezia benedeni*, *C. bovis*, *C. punctata*, *H. contortus* and *T. axei*) are common parasites in a variety of species of ruminants, and one (*G. pulchrum*) is cosmopolitan in

TABLE 2. Prevalence, intensity and maximum number of helminth parasites in fawn and adult axis deer from Puu-O-Hoku Ranch, Maui County, Molokai, Hawaii.

Helminth	Fawns (n = 5)	Adults (n = 5)
Cestoda		
Monezia benedeni	20/1/1[a]	—
Nematoda		
Capillaria bovis	40/2/2	—
Cooperia punctata	100/8/17	20/1/1
Gongylonema pulchrum	20/16/16	100/90/143
Haemonchus contortus	20/34/34	—
Trichostrongylus axei	60/315/778	—
Trichuris sp.	60/4/7	—

[a] Figures in columns are prevalence (%)/intensity/maximum number per host.

many different mammalian taxa (Soulsby, 1971). Results strikingly similar to those of the present study were found during evaluations of parasitism among white-tailed deer, feral cattle and wild swine and among white-tailed deer and domestic sheep (*Ovis aries*) from two different locations in the southeastern United States (Prestwood et al., 1975, 1976). For example, *M. benedeni, C. bovis, C. punctata, H. contortus, T. axei* and *G. pulchrum* were among eight species that occurred in both feral cattle and white-tailed deer (Prestwood et al., 1975) while *C. punctata* and *G. pulchrum* were among four species that occurred in both domestic sheep and white-tailed deer (Prestwood et al., 1976). As with this study, Prestwood et al. (1975) found that the helminth communities of intermingling populations of feral cattle and wild swine were distinct with very few shared species. Ables (1977) noted that axis deer and white-tailed deer on common range in Texas were both parasitized by *G. pulchrum, T. axei* and *Capillaria* spp.

An almost complete shift in the composition of the helminth community was noted between fawn and adult axis deer. The helminth community of fawns was dominated by *C. punctata* whereas *G. pulchrum* dominated in adults. Although factors involved in these differences were not investigated, *C. punctata* infections in domestic cattle are known to be age dependent with younger animals having higher intensities (Dunn, 1978), and *G. pulchrum* infections in white-tailed deer are reported to be higher in animals >6-mo-old (Prestwood et al., 1970). The drastic decline in the diversity of the helminth community in adult axis deer with the loss of essentially all species except *G. pulchrum* suggests that if cattle were removed many of the species found in axis deer might not be maintained in the deer population alone. Significantly higher infections of all shared species in cattle than in axis deer further suggests the importance of cattle in the perpetuation of these helminths.

The absence of any species of helminth in axis deer which could be considered unique to this host suggests that if any such indigenous helminths were present in the original founder animals they did not persist in subsequent generations. A virtual absence of indigenous helminths also was noted in introduced, free-ranging populations of sika deer (*Cervus nippon*), fallow deer (*C. dama*) and sambar deer (*C. unicolor*) that originated from small numbers of founder animals at various locations in the southeastern United States (Davidson et al., 1983, 1985, 1987). *Spiculopteragia assymetrica* in fallow deer was the only indigenous species that was found to have persisted in these populations of introduced exotic deer (Davidson et al., 1985). Similar to axis deer in this study, the parasite communities of these populations of sika, fallow and sambar deer appeared to have been derived primarily from sympatric populations of other ungulate hosts (Davidson et al., 1983, 1985, 1987). Furthermore, the parasites found in sika, fallow and sambar deer during these studies were species that exhibit little host specificity and also included *G. pulchrum* and *C. bovis* (Davidson et al., 1983, 1985, 1987). Comparable findings also have been reported among introduced ungulates in European game parks (Grafner, 1980; Kortla and Kotrly, 1980; Kotrly and Kortla, 1980). Taken collectively, these studies suggest that the indigenous parasite fauna of small founder populations of introduced exotic ungulates frequently does not persist in their free-ranging progeny and that subsequent parasite communities acquired from sympatric ungulates are of limited diversity and comprised primarily of species exhibiting a broad host range.

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