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HAEMONCHOSIS IN WHITE-TAILED DEER IN THE SOUTHEASTERN UNITED STATES[1]

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Abstract: Haemonchosis concomitant with malnutrition has been a frequent parasitic disease observed in white-tailed deer *(Odocoileus virginianus)* in the southeastern United States. Typically, afflicted deer were fawns from the southeastern coastal plain, and most cases were submitted between October and March. A survey of deer from 14 areas along the Atlantic coast revealed that fawns had significantly higher numbers of *Haemonchus contortus* than adults and in some areas fawns harbored *H. contortus* burdens that were considered pathogenic. The lower *H. contortus* burdens in adult deer suggested a naturally-acquired immunity. This hypothesis was supported by a trial in which challenge of small groups of *Haemonchus*-naive and previously exposed penned deer resulted in poorer performance of *H. contortus* in previously exposed deer. This study indicated that during their first winter fawns are particularly vulnerable to a haemonchosis/malnutrition syndrome.

INTRODUCTION

The pathogenicity of *Haemonchus contortus* has been recognized for decades, particularly in domestic cattle and sheep. Severe *H. contortus* infection also can be manifest as a disease syndrome in white-tailed deer *(Odocoileus virginianus)* as has been shown by reports of naturally-occurring haemonchosis in wild white-tailed deer[2,6,8] and by experimental infection trials.[3] Although *H. contortus* is known to occur in white-tailed deer in many regions of North America,[3,6,8,10,11,17] it is most common among deer in the Southeast, especially in the sandy coastal plain regions of South Carolina, Georgia, Florida, Alabama, Mississippi and Louisiana.[8]

Since the initial report of naturally occurring haemonchosis in a fawn from coastal Georgia,[6] personnel of the Southeastern Cooperative Wildlife Disease Study (SCWDS) have encountered additional cases in which haemonchosis was either a primary or contributing factor in clinical illness in white-tailed deer. In addition, state wildlife biologists in these regions occasionally have noted unusually poor fawn survival and have documented up to 30% annual mortality of fawns.[12] Previous parasite surveys[8] and herd health checks by the SCWDS revealed that although *H. contortus* was routinely present in adult deer in the coastal plain regions only rarely were the intensities of infection of sufficient magnitude to be clinically significant. Consequently, a study was undertaken to gain a better understanding of the bionomics of haemonchosis in white-tailed deer in this region. The major objectives of the study were to (1) deter-

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mine the prevalence and intensity of *H. contortus* infections in fawn and adult deer from selected populations in coastal plain regions between October and March, (2) determine the geographic region within which clinical haemonchosis might be expected to occur, and (3) determine if white-tailed deer could be immunized against *H. contortus* infection in a manner similar to domestic sheep.[1,13-15]

MATERIALS AND METHODS

SCWDS necropsy records from 1967 through 1979 were searched for the point of origin, date of submission, age, and sex of animals with clinical haemonchosis. Based on data from this retrospective study, a field investigation was designed and consisted of monitoring abomasal parasite burdens in fawns (< 1 yr.) on Deseret Ranch, Brevard and Osceola counties, Florida. Between October, 1977 and March, 1978, five collections of five fawns each were made at approximately 1-month intervals. In addition, five adult (≥1.5 yr.) deer were collected during January, 1978.

Field investigations subsequently were expanded to include sampling both fawn and adult deer from 14 study areas in the coastal plain of Florida, Georgia, South Carolina, and North Carolina. The major criteria for study site selection were availability of adequate specimens and previous parasitologic data. Background parasitologic data were available from SCWDS records and from abomasal parasite count (APC) studies[2] conducted by state wildlife agencies. Three areas (Dixon Memorial Forest, Bullard Creek Wildlife Management Area, and Deseret Ranch) were sampled during the late fall and winter of 1977-78 and 1978-79, whereas the remaining areas were sampled during the fall and winter of 1978-79. Deer population densities and habitats varied considerably among areas. Supplemental deer feeding programs were in effect on the Cat Island and Dee Dot Ranch areas.

Deer utilized during the field phases of the investigation usually were hunter-killed animals that were brought intact to check stations; however, collections specifically for research purposes were conducted at Cat Island, Buckfield Plantation, Deseret Ranch, and Tosohatchee State Preserve. With the exception of fawn-only collections at Deseret Ranch during 1977-78, an attempt was made to examine five fawns and five adults from each study area. Collection, processing and identification of abomasal parasites were according to the techniques of Eve and Kellogg[2] and Prestwood *et al.*[8] When feasible, blood samples were collected from fawns from Deseret Ranch for determination of packed cell volume, hemoglobin concentration, and total serum proteins.

After logarithmic transformation (log value +1) of data, a paired T-test was used to compare the mean number of *H. contortus* in fawns and adults from each area. Linear regressions of blood parameters and *H. contortus* burdens were calculated and tested for significance using confidence intervals. Prior to the latter computation, the values for *H. contortus* were converted to the number of parasites per kg of body weight to compensate for differences in body size of fawns.

For the laboratory phase of the investigation, six helminth-free white-tailed deer fawns were bottle fed until weaned and then fed a standard deer ration *ad libitum*.[16] The appropriate ration was determined for three deer and then restricted to one-half this amount 2 weeks prior to infection to increase the potential for high nematode burdens. At 36 weeks of age, these three deer were given an oral inoculum of 24,000 third stage *H. contortus* larvae (L_3) derived from a deer strain of *H. contortus*. The deer were returned to full rations at 19 weeks post-infection (PI). One week prior to infection and once weekly thereafter, blood samples were obtained for basic blood studies. All three deer were weighed weekly to determine weight changes during the course of infection. Fecal samples were taken once a week until the second week PI and then three times weekly until termination of the experiment. As the deer became patent, eggs per gram of feces (EPG) were determined by a modified McMaster's technique. All three deer were dewormed twice, once at 27 weeks PI with 2.00 grams of thiabendazole and once at 28 weeks PI with 0.25 grams *l*-tetramisole hydrochloride.

During this period, the remaining three deer were kept as controls in a helminth-free environment and fed full rations. Weekly fecal flotations were examined to insure that these animals maintained a helminth-free status.

Twenty-nine weeks after the initial infection, each of the six deer were given 24,000 L_3 *H. contortus* per *os*. The course of infection was monitored using the same techniques as described for the initial phase. Eight weeks PI, all six deer were killed and the abomasum, small intestine, cecum, and large intestine removed. The contents of each of these organs were processed by methods previously described.[2,9] In addition, the abomasum was digested in a pepsin/HCl solution to recover immature *H. contortus*.[5] The numbers of *H. contortus* recovered from each group of deer were compared using a paired T-test.

RESULTS

Cases of naturally occurring haemonchosis among white-tailed deer diagnosed by the SCWDS between 1967 and 1979 are presented in Table 1. Inspection of records revealed that such cases usually involved fawns from coastal plain areas and that most were submitted between October and March. In all instances malnutrition was considered a significant contributing factor by the diagnosticians. Lungworm *(Dictyocaulus viviparus)* infections, tick *(Amblyomma americanum, A. maculatum, Ixodes affinis, I. scapularis)* infestations, and trauma also were encountered as contributing factors. Case histories provided by wildlife biologists often stated that herds from which deer originated comprised unthrifty animals and that additional sick or dead deer had been observed. Diagnostic evaluations typically revealed subnormal weight or emaciation, dehydration, and anemia.

During the field phase of the investigation, nine species of abomasal parasites were recovered, including *H. contortus, Apteragia odocoilei, A. pursglovei, Ostertagia mossi, O. dikmansi, O. ostertagi, Trichostrongylus askivali, T. axei,* and *T. dosteri.* The average number of all species of abomasal parasites recovered along with the average number, range, percent prevalence, and percent abundance of *H. contortus* are presented in Table 2.

Haemonchus contortus occurred in deer from each study area in Florida, Georgia, and South Carolina but was not found in any of the four study areas in North Carolina. Fawns had significantly higher ($P<0.01$) average burdens of *H. contortus* than adults on each study area where it occurred except for Camp Blanding, Florida. Average burdens of *H. contortus* in fawns were as much as 141 times greater than in adults from the same area. *Haemonchus contortus* comprised from 10 to 94 ($\overline{X}=69$) percent of the total number of abomasal parasites in fawns from various areas whereas corresponding values for adults were from 0 to 33 ($\overline{X} = 10$) percent. The percent prevalence of *H. contortus* in fawns (50 to 100%) generally exceeded the prevalence in adults (0 to 100%) from the same area by 20 to 60%.

In fawns from Deseret Ranch, significant decreasing trends in packed cell volume ($t_0=2.47$; df=15; $P<0.05$), hemoglobin concentration ($t_0=3.76$; df=10; $P<0.05$) and total serum proteins ($t_0=6.28$; df=8; $P<0.01$) were noted as burdens of *H. contortus* (parasites/kg body weight) increased.

TABLE 1. Cases of naturally occurring haemonchosis in white-tailed deer submitted to the SCWDS between 1967 and 1979.

Location (County/State)	Date (Month/Year)	Weight (kg)	Number of *Haemonchus*	Additional Factors*
ADULTS				
Berkeley, SC**	11/67	21.6	2,568	Lungworms
Camden, GA***	8/73	23.4	1,700	Ticks
McIntosh, GA	2/75	13.5	959	Lungworms, ticks
FAWNS				
Long, GA	11/70	13.5	1,970	Ticks
Charleston, SC	8/71	16.2	6,496	Ticks
Long, GA	10/71	12.6	3,980	Lungworms
Hampton, SC	2/73	22.1	1,120	Lungworms
McIntosh, GA	11/74	7.7	2,120	Lungworms
McIntosh, GA	2/75	15.8	889	Ticks, trauma
Camden, GA	2/76	11.3	9,710	Lungworms
Camden, GA	2/76	15.8	15,751	Lungworms
Glynn, GA	3/76	11.3	6,509	Lungworms
McIntosh, GA	11/76	10.8	10,050	Lungworms, trauma
Glynn, GA	3/77	16.2	8,538	Lungworms, ticks
McIntosh, GA	3/79	11.3	340	Ticks

*These factors were considered contributory to debilitation or death; malnutrition was a contributing factor in all cases.
**SC = South Carolina
***GA = Georgia

In the laboratory phase of the investigation, the initial infections became patent 24-27 days PI. Fecal egg counts rose to 9,000 EPG during week 6 PI and declined to less than 100 EPG by week 21 PI. By week 5 PI, mean values for packed cell volume, hemoglobin, and total serum proteins had declined by 33, 32, and 17%, respectively. Values for all three returned to preinfection levels between weeks 12 and 19 PI. The feces of all three deer became negative for *H. contortus* eggs following administration of the anthelminthics.

The numbers of *H. contortus* recovered and prepatent periods for the challenge infection are given in Table 3. When compared to *Haemonchus*-naive deer, the total number of worms recovered from previously exposed deer was lower ($P<.10$). In addition, the previously exposed deer harbored lower ($P<.10$) numbers of adult and significantly higher ($P<.005$) numbers of immature *H. contortus*. Egg production was significantly lower ($P<.05$) in previously exposed deer and two of these deer never became patent (Table 3). During the challenge infection, changes in the blood parameters were not detected in either group of deer. The *Haemonchus*-naive deer experienced an average reduction in weight of 15% during the 8 weeks post-challenge while the previously exposed deer continued to gain weight during that period.

TABLE 2. Abomasal parasites recovered from fawn and adult white-tailed deer from 14 areas in the Southeast.

Location County/State	Date Mo./Yr.	Age Class/No.	Abomasal Parasites Avg. No.	*Haemonchus contortus* Avg. No.	*Haemonchus contortus* Range	*Haemonchus contortus* Percent Prevalence	*Haemonchus contortus* Percent Abundance*
Deseret Ranch							
Brevard and Osceola, FL**	10/77	Fawn/5	2604	2444	138-4197	100	94
	11/77	Fawn/5	3052	2825	291-6296	100	93
	1/78	Fawn/5	2500	2037	280-5912	80	82
		Adult/5	373	20	98	20	5
	2/78	Fawn/5	4517	4049	35-13,526	100	90
	3/78	Fawn/4	1705	653	45-2432	75	38
	12/78	Fawn/9	3699	3310	20-9036	100	90
		Adult/10	844	163	48-446	60	19
Tosohatchee State Preserve							
Orange, FL	2/79	Fawn/5	1196	732	120-1380	100	61
		Adult/5	800	84	60-269	60	11
Dee Dot Ranch							
Duval, FL	12/78	Fawn/4	900	842	180-1741	100	94
		Adult/4	195	16	64	25	8
Camp Blanding							
Clay, FL	1/79	Fawn/4	220	23	40-50	50	10
		Adult/5	352	25	20-62	60	7
Rotenberger Wildlife Management Area							
Broward, FL	11/78	Fawn/5	11452	10545	2516-15,574	100	92
		Adult/5	2516	833	50-4115	40	33
Bullard Creek Wildlife Management Area							
Jeff Davis, GA	12/77	Fawn/3	606	461	99-765	100	76
		Adult/5	447	47	16-143	80	11

TABLE 2. (continued)

Location County/State	Date Mo./Yr.	Age Class/No.	Abomasal Parasites Avg. No.	*Haemonchus contortus* Avg. No.	Range	Percent Prevalence	Percent Abundance*
	12/78	Fawn/5	848	401	28-817	100	47
		Adult/5	852	132	88-433	60	16
Dixon Memorial Forest							
Ware, GA	12/77	Fawn/3	1060	857	72-1260	100	81
		Adult/5	447	47	15-69	100	11
	12/78	Fawn/5	372	170	45-300	100	46
		Adult/5	624	14	72	20	2
Buckfield Plantation							
Hampton, SC	12/78	Fawn/5	1256	1126	60-2380	100	90
		Adult/5	328	8	40	20	2
Cat Island							
Georgetown, SC	12/78	Fawn/5	96	17	20-45	60	18
		Adult/5	144	0	0	0	0
Webb Center Wildlife Management Area							
Hampton, SC	10/78	Fawn/5	776	695	150-1760	100	90
		Adult/6	1090	205	43-890	50	19
	11/78	Fawn/5	460	217	110-537	80	47
		Adult/6	810	73	41-290	67	9
	12/78	Fawn/5	240	174	100-360	100	72
		Adult/5	604	10	52	20	2
Camp Lejeune							
Onslow, NC***	12/78	Fawn/5	304	0	0	0	0
		Adult/5	1708	0	0	0	0
Harrington Property							
Bertie, NC	12/78	Fawn/5	308	0	0	0	0
		Adult/5	916	0	0	0	0

TABLE 2. (continued)

Open Grounds Farm Carteret, NC	12/78	Fawn/5	60	0	0	0	0
		Adult/5	680	0	0	0	0
Sunny Point Military Ocean Terminal Brunswick, NC	12/78	Fawn/5	804	0	0	0	0
		Adult/5	1824	0	0	0	0

*Percent Abundance = Total number of *H. contortus* from all deer/total number of abomasal parasites for all deer.
**FL = Florida
***NC = North Carolina

DISCUSSION

Haemonchus contortus generally has been accepted as being pathogenic for white-tailed deer although comparatively few substantiating reports appear in the literature.[2,3,6,8] Our data support this contention since review of our records showed haemonchosis has been a frequently encountered parasitic disease of deer submitted to our diagnostic laboratory. Afflicted animals invariably were presented with a syndrome of haemonchosis and malnutrition often complicated by other parasites, especially ticks and lungworms.

Confirmation of diagnoses of the haemonchosis/malnutrition syndrome presented a difficult problem, primarily because guidelines of the pathologic significance of *H. contortus* burdens have not been established for white-tailed deer. In this regard, data from the literature and from the present study afford information from which preliminary guidelines may be formulated. Foreyt and Trainer[3] noted weakness, emaciation, and anemia in deer inoculated with 100,000 L_3 *H. contortus* of ovine origin whereas deer receiving 25,000 larvae retained a healthy appearance, although they developed a transient anemia. Averages of 3,005 and 1,329 adult *H. contortus* were recovered from the respective groups of deer. In the present study, deer maintained on one-half ration and inoculated with 24,000 L_3 *H. contortus* similarly developed a transient anemia and declined in physical condition. Reports of naturally occurring haemonchosis in deer include death of a malnourished fawn that harbored 16,540 *H. contortus*[6] and two separate episodes of excessive mortality in a deer herd during which times average burdens of *H. contortus* in adult deer were 1,034 and over 2,000.[2,8] In the present investigation, burdens of *H. contortus* in clinically ill deer ranged from 340 to 15,751 with most animals harboring approximately 1,000 or more *H. contortus*. Thus, available informa-

TABLE 3. Parasite recovery rates, prepatent periods, and egg production in immunized and nonimmunized white-tailed deer experimentally infected with 24,000 L_3 *Haemonchus contortus*.

	Immunized Deer			Nonimmunized Deer		
	No. 330	No. 333	No. 334	No. 328	No. 331	No. 332
Total Worms Recovered	649	848	3,433	3,510	2,920	10,760
Percent Inoculum Recovered	3%	4%	17%	18%	15%	54%
Number Adult Worms	9	8	3,433	3,510	2,920	10,760
Percent Adult Worms	1%	1%	100%	100%	100%	100%
Number Immature Worms	640	840	0	0	0	0
Percent Immature Worms	99%	99%	0%	0%	0%	0%
Prepatent Period (Days)	*	*	28	21	25	21
Maximum EPG	0	0	3,500	17,700	19,500	53,200

*Nonpatent infection

tion suggests an intensity of infection of near 1,000 *H. contortus* is the level at which pathogenic effects become detectable. This value is in agreement with similar values for domestic animals where burdens of 500 to 1,000 or more *H. contortus* have been considered pathogenic.[4] The actual intensity of infection at which pathogenic effects occur may be lower or higher than the above estimate depending on several variables such as age, size, and nutritional status of the host or the presence or absence of other complicating factors.

A plausible means of reducing variability due to host size (and age to a certain degree) is to evaluate burdens on the basis of number of *H. contortus* per kg of body weight. Inspection of blood data from fawns from Deseret Ranch revealed that values for PCV, Hb, and total serum proteins approached subnormal levels when burdens of *H. contortus* reached approximately 75 parasites per kg. Clinical cases in the present study harbored from 30 to 997 *H. contortus*/kg with 80% of the cases having 75 or more parasites/kg. Thus, infection intensities of approximately 75 *H. contortus*/kg body weight also can be used as a guideline for pathogenicity.

The lower burdens of *H. contortus* in adult wild deer suggested naturally acquired immunity, and this hypothesis was supported by the reduced infection intensities in previously exposed deer as compared to *Haemonchus*-naive deer of the same age. This finding was anticipated since various studies[1,13-15] have documented a similar phenomenon in domestic sheep. The immune response in deer, as in sheep, was directed toward reduction of larval take, inhibition of larval development, and reduction of egg production by female worms.

The timing of most clinical case accessions between October and March was considered relevant and most likely is related to two factors. The first factor involves the chronology of fawn development and behavior. Since fawns are not completely weaned until late summer or early fall, acquisition of a sufficient number of infective *H. contortus* larvae to stimulate an immune response, would not be expected to occur until later in the fall or winter. The second factor is related to seasonal changes in nutrition which reaches a low point during the winter and early spring. These two factors apparently coincide to form a critical aspect of the haemonchosis/malnutrition syndrome.

Furthermore, haemonchosis and malnutrition are additive.

In the southeastern United States, *H. contortus* has been found most commonly in deer in the sandy coastal plain region from South Carolina to Louisiana.[8] The present study further substantiates a distribution along the Atlantic coast southward from South Carolina. This helminth also is prevalent in deer from locales in southern Texas.[8,10] Thus, deer along the southern portion of the Atlantic coastal plain and probably the entire Gulf Coast from Florida to Texas should be considered as having the potential for morbidity or mortality due to the haemonchosis/malnutrition syndrome.

Apparently mortality due to the haemonchosis/malnutrition syndrome seldom is of sufficient magnitude to allow immediate recognition of die-offs although such instances have been reported.[2,8] Rather, mortality is of a covert nature with afflicted animals being found occasionally as with the present clinical cases; however, more intensive investigations usually revealed additional dead deer. Indication of haemonchosis may come only after the fact when a particular age class is not adequately represented in harvest data.

An additional, but unresolved, question in the epizootiology of *H. contortus* in deer in the Southeast is the role of domestic livestock, particularly cattle, in the maintenance of the parasite in deer. The possible influence of cattle on the occurrence of *H. contortus* in deer could be direct through cross-transmission of *H. contortus* or indirect through competition for food which would reduce the nutritional status of deer sharing a common range. The presence of cattle is not a prerequisite for the occurrence of *H. contortus* in deer.[8] However, observations that (1) locales where deer harbor *H. contortus* frequently have free-ranging livestock,[7,8] (2) intense competition with livestock for feed has been contributory to haemonchosis in deer,[6] and (3) *H. contortus* disappeared from deer on some areas when free-ranging livestock were removed[8] collectively suggest that domestic livestock, especially cattle, may exert an influence on the occurrence of *H. contortus* in deer.

The association between haemonchosis and malnutrition is more than casual and in most instances can be taken to indicate overpopulation of deer. Among the methods available to biologists for obtaining estimates of the status of deer density relative to habitat carrying capacity, the abomasal parasite count (APC) technique[2] has particular merit with regard to the detection of haemonchosis. For example, in locales where APC values and other parameters indicate that overpopulation exists, presence of *H. contortus* as a component of the APC in adult deer provides reason to suspect a haemonchosis problem in fawns. This suspicion can be verified or rejected by examination of fawns during the winter months.

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