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Authors: Fedynich, Alan M., and Rhodes, Olin E.

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## Hemosporid (Apicomplexa, Hematozoa, Hemosporida) Community Structure and Pattern in Wintering Wild Turkeys

Alan M. Fedynich<sup>1</sup> and Olin E. Rhodes, Jr.,<sup>2</sup> <sup>1</sup> Department of Pathology, Texas Tech University Health Sciences Center, 3601 4th Street, Lubbock, Texas 79430, USA; <sup>2</sup> Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina 29802, USA

**ABSTRACT:** The hemosporid community of 76 wild turkeys (*Meleagris gallopavo silvestris*) from South Carolina (USA) was examined using thin blood smears collected during January and February 1994. High prevalences and low abundances of hemosporids characterized this community. *Leucocytozoon smithi* and *Haemoproteus meleagridis* occurred in 100% and 54% of the turkeys, respectively; a *Plasmodium* sp. was found in one bird. Prevalence of *H. meleagridis* was significantly higher in juvenile turkeys than adults, but prevalences did not differ significantly among four trap sites or by host sex. Mean ( $\pm$ SE) intensities of *L. smithi*, *H. meleagridis*, and *Plasmodium* sp. were  $3.4 \pm 0.4$ ,  $1.8 \pm 0.3$ , and  $3.0$  per 10,000 erythrocytes, respectively. Abundances of *L. smithi*, *H. meleagridis*, and *Plasmodium* sp. were  $3.4 \pm 0.4$ ,  $0.9 \pm 0.2$ , and  $<0.1 \pm <0.1$  per 10,000 erythrocytes, respectively. Juvenile turkeys had higher rank abundance values of *L. smithi* than adults, whereas no differences were found among trap sites or between sexes. No differences in rank abundances of *H. meleagridis* were found among trap sites, host age, or host sex variables. Collectively, both common hemosporid species varied by host age, reflecting higher abundances in juvenile turkeys. Patterns of hemosporid prevalence appeared similar to patterns found in subtropical regions. Based on our data, we recommend using prevalence and abundance data to analyze the structure and pattern of hemosporid communities at the component community level.

**Key words:** Eastern wild turkey, *Meleagris gallopavo silvestris*, hemosporids, *Leucocytozoon smithi*, *Haemoproteus meleagridis*, *Plasmodium* sp., component community level, community ecology.

The wild turkey (*Meleagris gallopavo*) is an important game bird in North America. As such, its biology has been the focus of much research, particularly those factors associated with morbidity and mortality. Pathological responses have been reported in wild turkeys infected with *Plas-*

*modium hermani* (Forrester et al., 1980) and *Haemoproteus meleagridis* (Atkinson and Forrester, 1987). Although there have been numerous surveys for hemosporids in wild turkey populations, many workers have attempted to describe host-hemosporid systems using only hemosporid prevalence data and have made generalizations based on data summarized across seasonal and spatial variables or obtained using different collection techniques. Furthermore, models of host-hemosporid systems developed for temperate regions (Herman, 1968) may not be applicable where hemosporid transmission occurs throughout the year (Atkinson, 1991).

We undertook this study to evaluate a hemosporid community in a geographic region where vectors can occur throughout the winter. Our objectives were to determine species composition, prevalence, intensity, and abundance of hemosporids circulating in the peripheral blood of wild turkeys (*M. gallopavo silvestris*) from South Carolina (USA) during late winter, and to evaluate the relationship of host age, host sex, and trapping locality on hemosporids at the component community level.

Turkeys were trapped in January and February 1994 at four sites on the 80,981-ha Savannah River Site, which is operated by the U.S. Department of Energy and located in the upper coastal plain of South Carolina. Three sites (Site 1: 33°22'N, 81°39'W; Site 2: 33°19'N, 81°38'W; Site 3: 33°16'N, 81°35'W) were located in upland habitats and one site (Site 4: 33°7'N, 81°39'W) was in a swamp habitat. Turkeys were classified as juveniles or adults (Larson and Tabor, 1980) and the sex of each bird was determined. Each turkey was

banded and removed from the study area for use in state-sponsored relocation programs.

Two thin smears from each bird were made from blood obtained via brachial vein puncture. All smears were collected between 0600 and 1200 hr. Smears were fixed in 100% methanol and stained with Diff-Quick® (Dade Diagnostics, Inc., Aguada, Puerto Rico). To determine prevalence of hemosporids, both blood smears were examined for 30 min each at  $\times 1,000$ . For infected birds, 10,000 erythrocytes were counted and examined in 100 replicates of 100 erythrocytes each to provide an estimate of parasite intensity following recommendations of Godfrey et al. (1987). Few workers have quantified *Leucocytozoon* spp. on blood smears (Allan and Mahrt, 1989), possibly from concern over potential pooling of this parasite on the smear (Godfrey et al., 1987). However, based on regression analysis (SAS Institute Inc., 1985a) from a subsample of eight smears, *Leucocytozoon smithi* densities varied concordantly with densities of erythrocytes. Thus, pooling did not appear to be a significant factor.

Hemosporids were identified following the descriptions of Garnham (1966) and Greiner and Forrester (1980). Representative specimens were deposited in the International Reference Centre for Avian Haematozoa, Memorial University, St. John's Newfoundland, Canada (Numbers 144690 and 144691).

The terms prevalence, intensity, and abundance follow Margolis et al. (1982). Common hemosporid species were defined as those with  $\geq 20\%$  prevalence across the collective host sample. A value of 0.5 was arbitrarily assigned to birds that had hemosporid densities  $< 1$  per 10,000 erythrocytes to allow their inclusion in statistical analyses. Intensity and abundance data are presented as mean number of hemosporid individuals  $\pm 1$  SE per 10,000 erythrocytes.

Frequency data were analyzed with log-linear models (CATMOD; SAS Institute

Inc., 1985a) to determine if prevalences of the common hemosporids varied over the main (trapping locality, host age, and host sex) and interactive effects. The frequency distribution of abundance values for each of the common species and the residual errors generated from analysis of variance (ANOVA), were examined with univariate analysis for normality (SAS Institute Inc., 1985b). Because abundance values for each common hemosporid species were over-dispersed, the rank transformation procedure of Conover and Iman (1981) was applied to the data. We used a factorial ANOVA, for each of the common species, and a multivariate analysis of variance (MANOVA), for the collective common species, to examine the rank abundances of hemosporids for the main and interactive effects. For significant ANOVAs, means of the main effects were separated using the Tukey-Kramer test, whereas means generated from the interactive effects were separated by the least squares means procedure (SAS Institute Inc., 1985a). Interaction terms involving the independent variable trap locality were not analyzed because some cell sizes had  $< 10$  birds per cell.

Three hemosporid species were found in the 76 turkeys examined (Table 1). All turkeys were infected with *L. smithi*. *Haemoproteus meleagridis* was found in 54% of the turkeys; one turkey was infected with a *Plasmodium* sp.

Only *H. meleagridis* prevalence could be evaluated with log-linear analysis. Prevalence of *H. meleagridis* was significantly ( $P = 0.02$ ) higher in juvenile turkeys. Although males tended to have a higher prevalence of *H. meleagridis* than females, no significant differences ( $P = 0.53$ ) were found. Prevalence values between upland trap sites 1 and 3 were the most disparate, yet no significant differences ( $P = 0.31$ ) were detected among the four trap sites. No significant differences ( $P = 0.97$ ) were found for the interactive effect of host age and sex.

Intensities of *L. smithi*, *H. meleagridis*,

TABLE 1. Prevalences (%) of *Leucocytozoon smithi*, *Haemoproteus meleagridis*, and *Plasmodium* sp. found in 76 wild turkeys from South Carolina, January and February 1994.

Species	Locality				Host age		Host sex		Total
	Site 1 (n = 34)	Site 2 (n = 12)	Site 3 (n = 19)	Site 4 (n = 11)	Juvenile (n = 39)	Adult (n = 37)	Male (n = 38)	Female (n = 38)	
<i>L. smithi</i>	34 (100)*	12 (100)	19 (100)	11 (100)	39 (100)	37 (100)	38 (100)	38 (100)	76 (100)
<i>H. meleagridis</i>	15 (44)	7 (58)	14 (74)	5 (45)	26 (67)	15 (41)	23 (61)	18 (47)	41 (54)
<i>Plasmodium</i> sp.	1 (3)	0 (0)	0 (0)	0 (0)	1 (3)	0 (0)	1 (3)	0 (0)	1 (1)

\* Number of turkeys with this parasite (percent positive).

and *Plasmodium* sp. ranged from <1 to 16, <1 to 11, and 3 per 10,000 erythrocytes, respectively. Thirteen (17%) of 76 turkeys infected with *L. smithi* and 12 (29%) of 41 turkeys infected with *H. meleagridis* had intensities of <1 per 10,000 erythrocytes. Mean ( $\pm$ SE) intensities of *L. smithi*, *H. meleagridis*, and *Plasmodium* sp. were  $3.4 \pm 0.4$ ,  $1.8 \pm 0.3$ , and  $3.0$  per 10,000 erythrocytes, respectively.

Significant differences ( $P = 0.002$ ) in rank abundances occurred for *L. smithi* among host age groups (Table 2); juvenile turkeys had higher abundances than adults (Table 3). Collectively, both common species varied significantly by host age ( $P = 0.004$ , Table 2); juvenile turkeys had higher mean ( $\pm$ SE) abundances than adults ( $6.0 \pm 0.7$  and  $2.6 \pm 0.4$  per 10,000 erythrocytes, respectively). No differences were found in either of the two common hemosporids, or both species collectively, between trapping locality, host sex, or the interaction variable of host age and sex (Table 2).

TABLE 2. Values of the F statistic generated from factorial ANOVA for the two common hemosporid species and MANOVA (total) for both species collectively of the ranked abundance values among 76 turkeys from South Carolina, 1994.

Variable	<i>Leuco- cytozoon smithi</i>	<i>Haemo- proteus melea- gridis</i>	Total
Locality	1.84	0.73	1.21
Age	9.99*	2.87	5.97*
Sex	0.06	0.32	0.18
Age-sex	0.01	0.04	0.02

\* Significant at  $P \leq 0.05$ .

Workers describing host-hemosporid systems in temperate regions often report a seasonal aspect in transmission related to vector abundance (Allan and Mahrt, 1989). Typically, latent periods occur when vector populations are low or absent and represent periods in the host when hemosporid prevalence and intensity are low (Herman, 1968; Beaudoin et al., 1971). Alternatively, Atkinson et al. (1988) reported high (50 to 100%) prevalences and continual transmission of *H. meleagridis* throughout the year in southern Florida (USA) using domestic sentinel turkeys. Their findings were attributed to sufficient vector populations occurring throughout the year as a result of the subtropical climate. We found high prevalences and low intensities of the two common hemosporids during late winter, which is evidence that chronic infections probably resulted from continual hemosporid transmission.

Mild winter temperatures on our study area (National Oceanic and Atmospheric Administration, 1994), resulting from a southern maritime climatological influence, are capable of supporting vector populations. Jones and Richey (1956) found breeding populations of *Simulium slossonae* and *S. congareenarum* in early February in Jasper County, South Carolina. Noblet et al. (1975) found *L. smithi* was transmitted throughout the winter in the Coastal Plain and Sandhill regions of South Carolina. Unfortunately, annual abundance patterns of culicine mosquitoes (vectors of *Plasmodium* spp.), and of ceratopogonid and hippoboscids flies (vectors of *Haemoproteus* spp.) have not been ex-

amined within our study area or adjacent regions.

Host age clearly was related to the structure and pattern of the hemosporid community. Prevalence of *H. meleagridis* and abundance of *L. smithi* consistently were higher in juvenile turkeys. Age-specific host immunological status and physiological condition have been proposed as important factors in other host-hemosporid systems (Godfrey et al., 1990) and may have been a factor in our study. Turkeys tend to segregate into unisex flocks for extended periods (Healy, 1992), which could represent different exposure probabilities to vectors if habitat preferences were sex-specific. We found no differences in hemosporid prevalence or abundance between trapping locality (representing upland and swamp habitat types) or host sex variables.

We found one turkey infected with a *Plasmodium* sp. Apparently, this is the first record of a *Plasmodium* sp. in wild turkeys from South Carolina (Forrester, 1991). We were unable to determine the species, but it appeared similar to *Plasmodium* (*Novyella*) sp. reported by Castle et al. (1988). Sufficient differences were found in erythrocytic stages of this parasite to exclude either *P. hermani* or *P. lophurae*, which have been reported in wild turkeys from Florida and Wisconsin (USA), respectively (Forrester, 1991). Although subinoculation techniques were beyond the scope of this study, it is likely that more turkeys were positive for *Plasmodium* sp. than we observed.

Prevalence data often has been used as the exclusive means to describe hemosporid communities. However, our results provide strong evidence for using both prevalence and abundance data. For example, overall abundance of *L. smithi* was about three times higher than that found for *H. meleagridis*. Prevalences of *L. smithi* were similar across the biotic and spatial variables that we examined; yet juvenile turkeys had twice as many *L. smithi* than were found in adults. Also, the collective

TABLE 3. Abundances of *Leucocytozoon smithi*, *Haemoproteus meleagridis*, and *Plasmodium* sp. found in 76 wild turkeys from South Carolina, 1994.

Species	Locality				Host age			Host sex		Total (n = 76)
	Site 1 (n = 34)	Site 2 (n = 12)	Site 3 (n = 19)	Site 4 (n = 11)	Juvenile (n = 39)	Adult (n = 37)		Male (n = 38)	Female (n = 38)	
<i>L. smithi</i>	3.5 ± 0.5 <sup>a</sup>	1.9 ± 0.4	4.9 ± 0.9	1.9 ± 0.4	4.6 ± 0.5	2.1 ± 0.3		3.8 ± 0.5	3.0 ± 0.5	3.4 ± 0.4
<i>H. meleagridis</i>	0.7 ± 0.2	0.7 ± 0.2	1.6 ± 0.6	0.6 ± 0.3	1.4 ± 0.3	0.5 ± 0.1		1.4 ± 0.4	0.5 ± 0.1	0.9 ± 0.2
<i>Plasmodium</i> sp.	0.1 ± 0.1	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0.1 ± 0.1	0 <sup>b</sup>		0.1 ± 0.1	0 <sup>b</sup>	<0.1 ± <0.1

<sup>a</sup> Mean ± SE number of hemosporids per 10,000 erythrocytes.

<sup>b</sup> None found.

abundances of both common hemosporids were two times higher in juvenile turkeys than adults. Particular host subpopulations in which gametocytes are concentrated represent an important component in the maintenance of the host-hemosporid-vector cycle. Clearly, abundance data provides important information about the structure of hemosporid communities at the component community level and also provides insight about possible ecological relationships between hosts and their parasites, which could not be ascertained using only prevalence data.

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