Journal of Wildlife Diseases, 47(4), 2011, pp. 1047–1049

Gender Differences in Haemogregarine Infections in American Alligators (*Alligator mississippiensis*) at Savannah River, South Carolina, USA

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ABSTRACT: We report a host gender bias in haemogregarine infection characteristics in the American alligator (*Alligator mississippiensis*) at the Savannah River Site, South Carolina, USA. Prevalence and severity in female alligators was higher than it was in males. The reason for this pattern is not clear.

Infections with intracellular haemogregarine parasites are common in wildlife populations, and reptiles are particularly susceptible; surveys of hematozoa have revealed haemogregarine infections in populations of lizards (*Ameiva ameiva*; Bonadiman et al., 2010), snakes (*Liasis fuscus*; Madsen et al., 2005), turtles (*Trachemys scripta*, *Chrysemys picta*, and *Sternotherus odoratus*; Davis and Sterrett, 2011), and crocodilians (*Caiman yacare*; Viana et al., 2010). In American alligators (*Alligator mississippiensis*), at least one species of haemogregarine, *Haemogregarina crocodilinorum* Börner 1901, has been described (Telford, 2009). Cherry and Ager (1982) detected it in 20% of 30 alligators captured in Florida, USA. Hazen et al. (1978) reported that all 12 of the alligators they sampled from South Carolina, USA, were infected (although all had died from unknown causes), and Khan et al. (1980) found infections in 59% of 130 wild-caught alligators from throughout the southeastern United States. In all prior studies, no significant differences in prevalence were found between male and female alligators, and no gender differences have been reported for haemogregarine infections in other crocodilian species (Viana et al. 2010). We describe a survey of haemogregarine infections in a collection of wild-caught American alligators from the Savannah River Site (SRS) in South Carolina, USA, and report a clear gender difference in infection (prevalence and intensity) between sexes.

Alligators were sampled as part of a separate study at the SRS, in Aiken and Barnwell counties, South Carolina, USA. We examined Giemsa-stained blood films from alligators captured between 27 May 2010 and 21 September 2010. Films were examined under 1,000× (oil) with a standard light microscope, and all fields of view with even distributions of erythrocytes were examined for intracellular haemogregarine parasites. At least 100 fields of view were examined for each animal. Fields had an average of 71 (±13.7 SD) erythrocytes (based on counts of 12 random fields), so this was equivalent to examining approximately 7,100 cells per animal. If no parasites were seen, we assumed the animal was not infected. We also calculated the number of parasites per 100 cells to use as a measure of infection severity (parasitemia). This variable was log-transformed (+1) to approximate a normal distribution.

To explore possible gender biases in infection, we used logistic regression, where infection was the binomial response variable, gender and the month of capture (to account for possible seasonal effects) were explanatory variables, and total body length was a covariate. Then, using infected animals only, we used analysis of covariance to determine whether infection severity (response variable) differed between sexes (fixed factor) or varied with total body length (covariate). Because, in some months, there were few infected individuals, month was not included in this model. Analyses were conducted using Statistica 6.0 (StatSoft, Inc., Tulsa, Oklahoma, USA).

We sampled 76 alligators, 60 males and 16 females, ranging from 38 to 372 cm long. The larger number of males in the collection is consistent with the known male-biased sex-ratio of alligators at SRS (Brandt, 1991). From inspection of blood films, we detected haemogregarine infections in 37 alligators (49%). Although we did not attempt to identify the species of haemogregarine with molecular tools, it was morphologically consistent with the description of *Haemogregarina crocodilinorum* (Telford, 2009), with a general bean-shaped form within the erythrocyte cytoplasm and a notable displacement of the host cell nucleus (Fig. 1). The parasite measured 10.4 μm long and 4.3 μm wide, based on measurements of 20 random parasites, which is consistent with measurements reported by Khan et al. (1980), which indicated a range of 8–11 μm × 4–6 μm.

The logistic regression analysis of infection probability revealed no significant effect of month (df=4, χ^2=2.49, P=0.645) or body length (df=1, χ^2=0.65, P=0.419) on infection probability, but a significant effect of gender (df=1, χ^2=6.57, P=0.010); prevalence of infection was 69% in females and 42% in males. The analysis of infection severity uncovered no effect of body size ($F_{1,23}$=0.247, P=0.624), but a near-significant effect of gender ($F_{1,23}$=3.170, P=0.088). Infected female alligators had an average of 0.24% (±0.23 SD) of cells with haemogregarines, which was nearly twice as high as the average number of affected cells in males (0.14±0.15%).

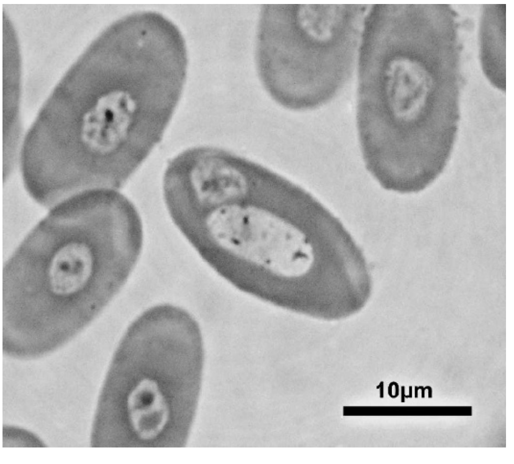

FIGURE 1. Haemogregarine parasite (presumed *Haemogregarina crocodilinorum*) in an erythrocyte of an American alligator from the Savannah River Site, South Carolina, USA.

The frequency of haemogregarine infection in this alligator population (49%) was consistent with prior surveys of southeastern populations (Khan et al., 1980). However, the higher probability of infection in female alligators found here, along with the tendency for females to have higher parasitemias, was in marked contrast to the reports of Khan et al. (1980) and Cherry and Ager (1982) from South Florida, USA, both of which reported no gender bias in prevalence. Moreover, in similar surveys of other crocodilian species, no sex-related differences in prevalence of haemogregarines were found (Viana and Marques, 2005; Viana et al., 2010). This disparity probably does not stem from differences in the time of year between studies because Khan et al. (1980) sampled in the summer months as we did. It is also not likely due to gender differences in body size because there were no such size differences in the animals we sampled, plus there was no effect of body size on infection probability or severity, nor can these contrasting results be attributed to any particular peculiarity of the alligator population sampled here (i.e., at the SRS). Despite the alligators in this study being collected near to a former nuclear facility, there is evidence that alligator populations at the largest water body at SRS (Par Pond), have been increasing over time (Brandt 1991), suggesting a population in good health.

The reason for the gender bias in infection is not clear. It could be that the behavior of female alligators differs from males in some way as to make them more prone to encountering the parasite vector (i.e., leeches). American alligators show sex-related differences in home range size and site fidelity, especially during the nesting season, when females tend to stay near swampy areas (near nests), whereas males stay in open water (Goodwin and Marion, 1979). However, prior surveys of leech infestations on *A. mississippiensis* (in Texas, USA) have shown no difference in leech loads between males and females (Smith et al., 1976). Whether this behavioral difference contributed to the gender difference in infection at SRS is unknown. These results emphasize the dynamic nature of host-pathogen relationships and that conclusions drawn from prior studies may not hold for all locations and time periods.

We thank David Kling, Cris Hagen, Kurt Buhlmann, Jaclyn Mills, and several volunteers for assistance with capturing alligators. We also thank Sonia Altizer for helpful discussions during the preparation of this manuscript. This research was partially supported by the Department of Energy under Award DE-FC-09-075R22506. All samples were collected under South Carolina Department of Natural Resources collection permit G-10-02. Animal capture and handling protocols were approved by the University of Georgia Institutional Animal Care and Use Committee, protocol A2008 11-035.

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Submitted for publication 30 September 2010.
Accepted 15 June 2011.